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Fire Behavior Computations with the Hewlett-Packard HP-71B Calculator

**Ronald A. Susott
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RESEARCH SUMMARY

A Custom Read Only Memory (CROM) has been developed for the Hewlett-Packard model 71B handheld calculator for fire behavior computations. The calculator replaces the Texas Instruments TI-59. The CROM programs allow many computations not found in the TI-59 version and implement most of the programs in the BURN subsystem of the BEHAVE fire behavior prediction system. An additional metric mode is included in the programs. A separate CROM was developed for computing the 1978 National Fire-Danger Rating (NFDR) indexes and components, and a separate user's manual has been published: Burgan, Robert E.; Susott, Ronald A. Fire Danger Calculations with the Hewlett-Packard HP-71B Calculator. General Technical Report INT-199. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 16 p.

This report describes the operation of the HP-71B program for fire behavior predictions, the inputs needed, and outputs calculated for each of 13 separate program modules. Sample worksheets are included and worked examples are given for each module of the program.

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INTRODUCTION

The Hewlett-Packard HP-71B has been selected to replace the Texas Instruments TI-59 (Burgan 1979) for field computations of fire danger and fire behavior. This manual describes operation of the fire behavior programs as implemented on the HP-71B. The programs are intended for field use by fire behavior analysts who are familiar with the methods for gathering input data, for interpreting program outputs, and for applying these data to fire problems. Rothermel (1983) has described the methods needed to predict fire behavior. Operation of a separate program written for fire danger rating applications is described in a companion publication (Burgan and Susott 1986). Each program is available as a separate Custom Read Only Memory (CROM).

Separate self-study guides have been prepared for the fire danger and fire behavior programs. These are available through your agency coordinator, who will distribute the guides and help answer questions about the calculator and the course material.

The HP-71B fire behavior program is patterned after the BURN subsystem of the BEHAVE fire behavior prediction and fuel modeling system (FIRE1 and FIRE2 programs). The keywords, program organization, line numbers, and worksheets are similar to those of BEHAVE. The majority of the papers describing the BURN subsystem (Andrews 1986) describe the models used for the calculations, their limitations, and applications. Technical references given there are not repeated here. It is strongly recommended that the reader be familiar with those papers.

CALCULATOR FEATURES

The HP-71B has several features that make it more suitable for field use than the TI-59 it replaces:

- A liquid crystal display (LCD) that is easy to see in daylight.
- The capability to display both alphabetic and numeric characters.

This eliminates the need for keyboard overlays because requests for input and displayed output can be appropriately labeled.

- Use of complementary metal oxide on semiconductor (CMOS) architecture which, because of its very low power requirement, permits many hours of operation between battery changes.
- Use of replaceable, rather than rechargeable, batteries.
- A continuous memory that retains the information stored in the calculator even when the calculator is turned off.
- A capability to be used with optional battery-operated printers, data cassettes, and disk drives.
- A powerful BASIC programming language that is available for many other user applications.

PROGRAM FEATURES

The fire behavior program for the HP-71B implements much more fire behavior technology than was possible with the TI-59. Program capabilities are indicated by the following list of program modules and their functions:

- FUEL MODEL - permits inputting, loading, listing model names or values, saving and deleting models.
- DIRECT - calculates spread rate, heat per unit area, fireline intensity, flame length, reaction intensity, effective windspeed, and direction of maximum spread.
- SIZE - calculates area, perimeter, length-to-width ratio, forward spread distance, backing spread distance, and maximum fire width.
- CONTAIN - calculates length of fireline at containment time, time to containment, and final fire size or required line-building rate.
- SPOT - calculates maximum spotting distance.
- SCORCH - calculates scorch height.
- IGNITE - calculates probability of ignition.
- MOISTURE - calculates 1-hour timelag fuel moisture, fuel level temperature and relative humidity, percentage of area shaded, and probability of ignition for either a specific burn time or as hourly calculations.
- MAP - calculates fire dimensions, spread distance, and maximum spot distance for plotting on a map.
- SLOPE - calculates slope steepness, elevation change, and horizontal distance.
- WIND - calculates midflame windspeed from the windspeed measured 20 feet above the general vegetation surface.
- RH - calculates relative humidity and dew point.
- TWO - calculates weighted rate of spread for the two-fuel-model concept.
- PRINTER - not a module, but provides the option of directing output to a printer.

The 13 standard fire behavior fuel models (Anderson 1982) are included in the CROM. Up to 19 additional user-defined fuel models (numbered 14-99) can also be

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entered, and stored in the calculator memory. The fuel modeling subsystem of BEHAVE (Burgan and Rothermel 1984) is strongly advised for the development and testing of user models before their entry into calculator memory.

The program has a metric version that provides for both metric inputs and outputs. Separate data sheets are provided for the English and the metric versions. These data sheets are at the end of this report.

Operation of the fire behavior program will not alter any values assigned to variables created in other programs and saved in continuous memory. Some global flags and system characteristics such as DELAY, OPTION BASE, DEG/RADIANS, Display Format, and Round-off Setting are changed by the program and not reset. User programs that need these system flags or characteristics should be written to correctly initialize them. Refer to the HP-71 Reference Manual for more detailed information.

Operation of the BEHAVIOR program uses a large portion of the HP-71B memory. Large user files or previously defined variables can cause the "Insufficient Memory" error at unpredictable locations in the program. The "DESTROY ALL" statement may reclaim enough memory to run the program, or files can be removed with the "PURGE" statement. Users who frequently have large files in memory should consider obtaining the optional memory expansions available for the HP-71B.

PROGRAM STRUCTURE

When BEHAVIOR is run, the program first enters the MAIN module. The MAIN module's only function is to call other modules that actually perform the desired calculations. Figure 1 shows that the structure of these other modules is divided into three levels. The first level is called directly from MAIN, and the modules in level 1 can be run independent of other modules. Once calculations have been made in a level 1 module, that module can call the next level and pass calculated outputs to it. The called level is said to be "linked" to the calling module through the information passed. For example, a DIRECT-SIZE-CONTAIN run will pass DIRECT outputs to SIZE and both DIRECT and SIZE outputs to CONTAIN. The run outputs from a module can be passed to any of the modules available for linking. For example, level 2 SIZE outputs can be linked to MAP to convert the spread distances to map distances. When MAP is Quit and the program returns to SIZE, a link to CONTAIN uses the same outputs from the last SIZE run to calculate containment times. All outputs of a module Run are valid until new inputs are made or the module is Quit. Modules shown in figure 1 that cannot call other modules cannot pass outputs to any other module. For example, the 1-hour moisture calculated by the MOISTURE module cannot be passed to DIRECT. Of course, such a calculated moisture can be manually entered when running the DIRECT module.

Modules are selected through use of their two-letter keywords—the underlined letters in the module name in figure 1. Additional, generally single letter, keywords are used to perform specific tasks within each module. The large ENDLINE key is used to complete all user entries. Once a module is selected, its keywords are operative and will appear in the display. The Quit keyword is used to move one level to the left in figure 1. Each level must be Quit to return to the MAIN level where you can select another module or Quit the program.

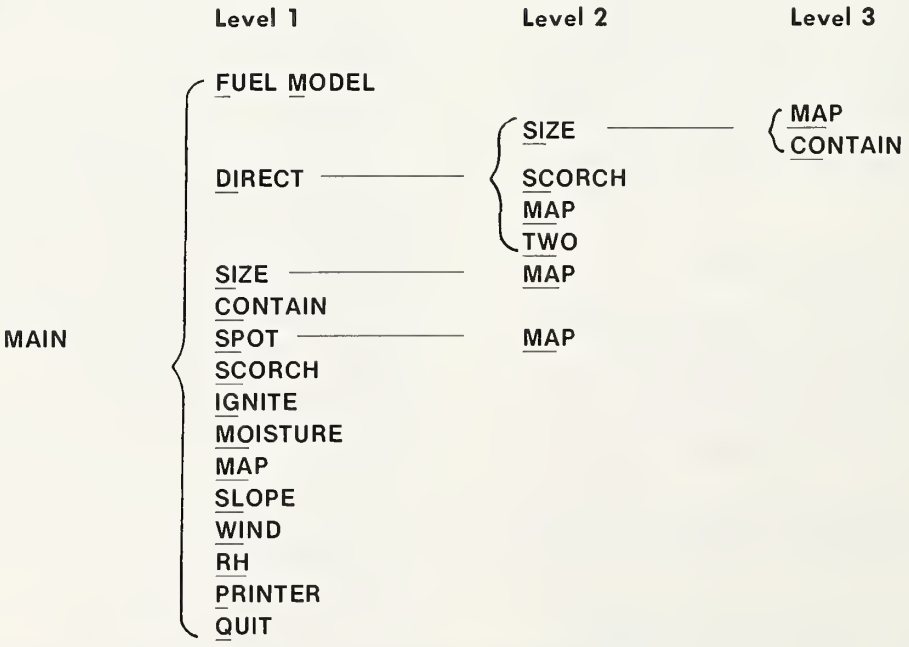

Figure 1.—The HP-71B fire behavior program structure.

GENERAL PROGRAM OPERATION

Operation of the MAIN Section

After the HP-71B has been turned on, the fire behavior program can be started in either of two ways:

1. Type in RUN BEHAVIOR and press the ENDLINE key. This will always start the program at the beginning.
2. If the fire behavior program was the last program run before the calculator was turned off, just press the RUN key.

When the program starts running, the letters PRGM will appear in the right side of the display, followed immediately by a short display of the words "FIRE BEHAVIOR". The program then asks whether or not you want the metric version and slope in degrees. Entry of No to these questions, or just pressing ENDLINE, gives the defaults of English version and slope in percent. If a printer is attached, and **turned on**, the message "PRINTER ON" is briefly displayed; otherwise the message "NO PRINTER AVAILABLE" is briefly displayed. Finally, the program indicates you are in the MAIN section by displaying the message "MAIN: FM,DI,SI,SP". This is the MAIN module prompt and the characters following the colon are a menu of keywords for the allowable modules. The remainder of the MAIN section module keywords may be seen by repeatedly pressing the ∧ or the ∨ keys. The other prompts displayed are:

"MAIN: CO,SC,IG,MO";

"MAIN: MA,SL,WI,RH";

"MAIN: P,Q".

The display sequence repeats if the ∧ or ∨ keys are pressed several times. When you are in the MAIN section you can go to one of the modules, set the Printer to on or off, or Quit by entering the appropriate keyword and pressing ENDLINE. The keyword does not have to be currently displayed. Any incorrect entry will just disappear when you press ENDLINE and you can try again.

Normal termination of the fire behavior program is by using the keyword Quit when you are in the MAIN section. You may turn the calculator off any time the program waits for user input, by pressing the gold f ON to invoke the "OFF" command. The calculator will also automatically turn off if there is no activity for about 10 minutes. In these last cases, when the calculator is turned back on, the SUSP annunciator will appear in the display indicating program operation is now suspended. The best way to continue from this point is to press the gold f + for the "CONT" or continue command and a question mark "?" will appear. This indicates the program is still waiting for input of the item being requested when the calculator was turned off. If you do not know what to enter, press the + key (or any nonnumeric), then press ENDLINE, and the display will prompt for the requested input. Pressing the RUN key, or entering "RUN BEHAVIOR", will restart a suspended program from the beginning and previous work will be lost. Failure to end the program by quitting from MAIN will result in abnormal functioning of some calculator keys.[1] If this happens, enter "RUN BEHAVIOR" and Quit when the display reads "MAIN: FM,DI,SI,SP?". This will return the calculator to normal operation.

Input and Output Procedures

The program will not accept values outside a reasonable range assigned to each item. Although the program does limited checking of the completeness of the inputs, you should be certain the inputs are correct before doing any computations. On the other hand, inputs that do not change from run to run only need to be entered once. If there is any question as to whether or not the inputs are correct, they should be listed before the program is run.

All the modules employ the same techniques for data entry and modification. The inputs for each module have been numbered (see data sheets) and arranged in a specific sequence.

All inputs are initialized to −100 each time you start the program by entering "RUN BEHAVIOR" or by pressing the RUN key. If you do a series of runs, previously defined inputs will remain, thus always list your inputs and check their values before calculating outputs. The program will prompt for those inputs needed by the module being run and check whether or not a value has been entered for all required inputs. Valid inputs are limited to reasonable ranges as shown with the input prompt and listed on the data sheets. If you attempt to enter nonvalid data, it will simply disappear from the display and you may try again. If you have entered an input and it appears that the calculator is not proceeding, the reason is that your input was probably outside the permissible range and you are being asked again for the same input. In general, inputs to one module are not passed to other modules at the same level; exceptions are the fuel model number and map inputs common to MAP and SLOPE.

ENTERING AND LISTING INPUTS

To enter or list input items, you can:

- begin inputting or listing data at the first item in the list by entering I or L, respectively, followed by an ENDLINE. This is the normal procedure for input and will ensure that all needed entries are made.
- begin inputting or listing data at any item number by entering I# or L# respectively, where # is the item number (as shown on the data sheets). A space between L and # is optional. For example, entering I4 when the display reads "DIRECT: I,L,R,Q?" will allow entry of 100H moisture (fourth item in the DIRECT list).

Once you have started entering input data at some point in the input list, the program continues sequentially down the input list. Entry of inputs can be terminated at any time by pressing ENDLINE without first keying in an entry. This will not affect the input parameter whose value is being requested.

[1]The program uses key files named KEY0, KEY1, and KEY2. Do not use these names for any other purpose.

The program permits entry of only one value for some input items, but 1, 2, or 3 values may be entered for others. Single value items are indicated in the calculator display, by parentheses ( ) surrounding the valid range. These items also have only one entry line on the data sheets. Multiple value items are indicated in the display by square brackets [ ] surrounding the valid range. These items have three entry lines on the data sheets. Multiple values are entered by keying in each number, separated by a comma;[2] that is, 4, 6, 8 and pressing ENTER. Thus, depending on the inputs specified, you can obtain:

- a single output value for each output item by entering only one value for each input item
- a list of 2 or 3 output values for each output item by entering 2 or 3 values for one of the input items
- a table of up to 9 output values for any one of the output items by entering 2 or 3 values for two of the input items.

Input listing can be started at any point by entering L#. If no printer is attached, the display pauses after each line is shown. Subsequent items can be listed by pressing the ∨ key. Previous items can be listed by pressing the ∧ key. Terminate the listing by pressing ENDLINE. When a printer is attached, there is no pause between list items; all remaining items will be printed without pressing any keys.

Values can be input with more decimal places than shown on the listings. The values listed are rounded to fit on the display, but the full precision of the numbers entered is used for calculations. Numbers that must be integers, however, are truncated by the program. For example, if a CONTAIN run option of 1.8 is entered, it will be changed to 1.0.

CHANGING INPUTS

The value of individual input items can be changed by entering I# where # is the number of the input parameter to be changed. The display will show that you are to enter the value for the item requested. Enter the value and press ENDLINE. The next input item will then appear in the display, but if you do not want to change its value, just press ENDLINE.

CORRECTING ERRONEOUS INPUTS

Erroneous entries or typing errors can be corrected before the ENDLINE key is pressed by:

1. Holding down the gold f key and either pressing the < key repeatedly, or holding the < key down. This invokes the "BACK" command printed in gold letters on the calculator. The last entries are deleted by this operation.
2. Pressing or holding the < key to back up the cursor, then deleting the unwanted characters by pressing or holding the gold f key and then the > key. This invokes the "−CHAR" command.
3. By using the < key to back up the cursor, then typing in the correct inputs. If extra characters remain, they can be deleted individually by using the "−CHAR" command or replaced by using spaces.

Refer to the HP-71B Owner's Manual for more detailed line-editing instructions.

OBTAINING OUTPUTS

After you are certain the input values are correct, outputs may be obtained by:

- Entering R (for RUN) to start at the beginning of the output list.
- Entering R# to start at the location of the item number specified. This is normally used to review the value of specific output items after completing a valid run.

At the start of a run, the input list is checked. If the inputs are not complete when a run is attempted, the calculator will beep and display the message "INCOMPLETE INPUT". In this case, list the inputs to discover which inputs still have a value of −100, then enter correct values.

If more than two input items are assigned multiple values, the error message "EXTRA MULTI-INPUTS" is displayed. In this case, list your inputs to find which one can be assigned a single value.

After a valid run, the output listing starts automatically. If you are not using a printer, you may scroll up or down the output list by repeatedly pressing the ∧ or ∨ keys, respectively. Output listing is terminated by pressing ENDLINE. If the output is going to a printer, the ∧, ∨, and ENDLINE keys are deactivated and the list is printed from your starting point to the end of the list.

List output is produced (two or three columns for each output), by assigning two or three values to one input item. The first line displayed is the labeled input line for which multiple values were input. Press the ∨ key to display the labeled output line. The output line consists of: the output line number, the mnemonic label, and the two or three output values. After recording the outputs, press the ∨ key to continue. At times the output line can contain more than 22 characters and the first few characters will scroll off the display.

A table is produced by assigning two or three values to each of two input items. You must select the table entry item by its output number "TABLE #(Ø-N)" where N is the number for the last output item for the module you are in. The output numbers are given in the data sheets. For example, entry of 4 for table number when you are in the DIRECT module will produce a table of flame lengths—DIRECT output item 4. Entry of Ø will terminate the table listing, as will ENDLINE with no entry.

The first line of table output consists of four items that identify the table being produced. These are table number, table item, row item, and column item. Refer to the DIRECT module data sheet for the following example. An example display for a flame length table in DIRECT is: 4 FL 1H * MFWS. This identifies the output item to be displayed in the body of the table as output number 4, which is flame length (FL). Each row will be for a different 1-hour timelag fuel moisture (1H) and

[2]Only specific input values can be entered into the calculator, rather than the beginning value, ending value, stepsize as in BEHAVE. For the calculator, the values can be entered in any order.

each column for a different midflame windspeed (MFWS). Enter this type of information above the dashed line across the "table" form at the end of the worksheets.

The next display line, obtained by pressing the ∨ key once, is the input values for the column item. An example display is 6 8 11. Enter this type of output on the three lines above the words "Table Values."

The next three output lines are of the form—row number: row value column 1 column 2 column 3 values. An example display of—1:4.0 8.3 10.3 13.2 indicates that for row 1 which has an input value of 4, the table values are 8.3, 10.3, and 13.2 The row number is prerecorded on the data sheet form. Enter the remaining values for each row as you obtain them by pressing the ∨ key to scroll down the outputs. You may also scroll up through the outputs by pressing the ∧ key. Continue scrolling until the module label and keywords reappear, for example, "DIRECT: I,L,R,Q?".

If output is being directed to a printer, separator lines (= = = = =) will be printed to help distinguish the input from the output. If a printer is not being used, these lines will only flash briefly on the display. As with other lists, the entire table is printed without using the scroll keys.

The calculator makes as many "RUNS" as necessary for the number of outputs you requested; that is, one run for a single set of outputs, up to nine runs for a 3 × 3 table containing nine output values. The "RUN" number is displayed as each "RUN" starts. All runs are completed before any outputs are available for listing. Several modules require lengthy calculations and some patience is needed while the runs are being completed.

OPERATING THE MODULES "INDEPENDENTLY"

The FUEL MODEL Module

The purpose of this module is to permit entry of a site-specific fire behavior fuel model into calculator memory. It is strongly advised that such models be developed and tested through use of the FUEL subsystem of BEHAVE before entering them into the calculator. (See Burgan and Rothermel [1984] for detailed information on developing fuel models.) Fire behavior cannot be calculated with this module—it is strictly for managing and maintaining a file of user fuel models.

When the calculator display shows—"MODEL: G,I,L,S,Q?"—you are in the fuel model module. Pressing the ∧ key shows an alternate prompt "MODEL: LM,DM" for additional menu selections. While in the fuel model module, you may:

• Get a standard model (numbered 1-13) or a site-specific fire behavior fuel model (numbered 14-99) by entering G and a number. For example, you can get model 14—if it has been previously entered and saved—by keying in G14 and pressing ENDLINE. If the requested model is available, the display will show "MODEL # LOADED", where # is the requested model number. If the model is not available, the message "MODEL # NOT FOUND" is displayed and another input requested. Alternatively, you can just enter G and the calculator will then request a model number.

• Input all the data for a new model by entering I when the display shows—"MODEL: G,I,L,S,Q?". The program recognizes that some inputs are not always required. For example, if the WOODY LOAD is entered as zero, the WOODY S/V ratio input will not be requested. HERB TYPE and HERB S/V ratio are similarly linked to HERB LOAD. Individual parameters can be input or changed by referring to their line numbers. For example, I3 will cause the calculator to request a value for 1HR LOAD, the third item in the FUEL MODEL input list. This procedure will allow input of herbaceous and WOODY S/V ratios and HERB TYPE even if they are not needed. The values assigned to unneeded inputs are saved in the user fuel model files, but they have no effect on calculations.

• List the current values from the beginning (by entering L) or from any other location in the list by entering a line number with the L, for example, L3, and repeatedly pressing the ∨ or ∧ keys.

• Save a model in the user model files, which the program automatically creates for you.[3] If you just Get an existing model from the file and try to Save it without renumbering it, the calculator will beep, briefly display the fact that the model already exists, then ask if you want to "KILL OLD XX (Y/N)?" where XX is the model number. This gives you the options of replacing the existing fuel model (Y), or not saving the model (N). Entering N avoids replacing an existing fuel model with the same number. The model number can be changed to an unused number before saving. When a model is successfully saved, the display will read "MODEL # SAVED", where # is the model number. Up to 19 models can be filed with any model number from 14 to 99. The order of entry of different model numbers is not important; for example, model 99 can be entered and saved first. An attempt to save more than 19 models will result in an error message "USER FILE IS FULL" and the model will not be saved. The way to save the model at this point is to either change the model number to that of an existing user model (which is no longer needed), or to delete one of the existing models (see below). You can get models 1 to 13 and make changes, but they can only be saved if the model number is changed to 14 to 99. The program prompts for a model number in the correct range and a name before completing the Save operation.

• List Models to obtain a list of all the models in the user model files, by number and name. A message "NO USER MODELS" will be displayed if the file is empty. Scroll up and down through the list with the ∧ and ∨ keys. The contents of the file may be recorded in the form provided after the Fuel Model Module form.

• Delete Models allows you to delete individual fuel models from the file. When the display reads "DELETE MODEL (14-99)?" enter the number of the model to be

[3]Up to four model files are automatically created in memory, named: USERMOD0, USERMOD1, USERMOD2, and USERMOD3. These names should not be purged or used for other purposes.

deleted. If that model is not in the file, you will get the message "MODEL # NOT FOUND" and another request for the number of the model to be deleted. If the model you want to delete is in the file, the display will read "DELETE # (Y/N)?". If you enter Y, the model will be deleted from the file and another model number requested. Terminate deletions by pressing ENDLINE with no model number entered in the display.

• Quit to exit the fuel model module. If a valid model is not present when Quit is selected, the error message "INCOMPLETE INPUT" is displayed. The program will not Quit the fuel model module until the model has all needed inputs. List will show a −100 for missing inputs. User fuel models should normally be Saved before quitting this section, although a temporary fuel model can be entered and used for calculations in other modules. Any fuel model you Get or build in this module will also be assigned to any other module requiring a fuel model. The normal procedure is to assign fuel models as required by each module you operate.

The DIRECT Module

The prompt "DIRECT: I,L,R,Q" indicates that you are in the DIRECT module. An alternate DIRECT menu "DIRECT: SI,SC,MA,TW" is displayed by pressing the up arrow, ∧ , when the module prompt is shown. These modules can be linked to DIRECT after a valid Run is made, as discussed later.

The DIRECT module provides five outputs that describe the general characteristics of the fire (1 through 5). The effective windspeed (6) is for the direction of the spread calculation, whether or not that is the direction of maximum spread rate. If either the slope or windspeed is greater than Ø , the input of spread direction (input item 10) is preceded by the question: "PREDICT AT MAX (Y/N)?". If the answer is N, item 10 is requested, but if the answer is Y, item 10 is not entered and all predictions will be in the direction of maximum spread. The direction of maximum spread (7) is output if predictions are in the direction of maximum spread. A list of inputs will show a "MAX" for spread direction whenever the calculations are made in the direction of maximum spread rate. Exhibit 1 shows three runs that provide typical examples of using the DIRECT module. A table of values for any other DIRECT output could also be generated from the input list in exhibit 1c. Exhibit 1e shows a printer list for the above examples: The format for the printer output is the same as display output without a printer.

DIRECT MODULE (English Units)

LIST NUMBER 22a

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		3	
2	1H	1-H fuel moisture	[1-60%]	6.0		
3	10H	[1]10-H fuel moisture	[1-60%]	—		
4	100H	[1]100-H fuel moisture	[1-60%]	—		
5	HERB	[1]Live herb moisture	[30-300%]	—		
6	WOOD	[1]Live woody moisture	[30-300%]	—		
7	MFWS	Midflame windspeed	[0-99 mi/h]	8		
8	SLP	Slope	[0-100% or 0-45 degrees]	30%		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	20		
	PREDICT AT MAX		(Y/N)		Y	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]			MAX
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	228		
2	H/A	Heat per unit area	Btu/ft^2	742		
3	FLI	Fireline intensity	Btu/ft/s	3,102		
4	FL	Flame length	ft	18.2		
5	RI	Reaction intensity	Btu/ft^2/min	2,900		
6	EWS	Effective windspeed in direction SDIR	mi/h	8.4		
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	19		

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 1a.—DIRECT run obtaining a single set of outputs.

DIRECT MODULE (English Units)

LIST NUMBER 226

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		3	
2	1H	1-H fuel moisture	[1-60%]	6.0	9.0	12.0
3	10H	[1]10-H fuel moisture	[1-60%]	–		
4	100H	[1]100-H fuel moisture	[1-60%]	–		
5	HERB	[1]Live herb moisture	[30-300%]	–		
6	WOOD	[1]Live woody moisture	[30-300%]	–		
7	MFWS	Midflame windspeed	[0-99 mi/h]	8		
8	SLP	Slope	[0-100% or 0-45 degrees]	30%		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	20		
	PREDICT AT MAX		(Y/N)		N	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]	10		
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	189	155	136
2	H/A	Heat per unit area	Btu/ft^2	742	673	648
3	FLI	Fireline intensity	Btu/ft/s	2,574	1,912	1,620
4	FL	Flame length	ft	16.7	14.5	13.5
5	RI	Reaction intensity	Btu/ft^2/min	2,900	2,628	2,532
6	EWS	Effective windspeed in direction SDIR	mi/h	7.3	7.3	7.3
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	–	–	–

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 1b.—DIRECT run obtaining a list of outputs for a range of three 1-hour moisture inputs.

DIRECT MODULE (English Units)

LIST NUMBER 22c

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		3	
2	1H	1-H fuel moisture	[1-60%]	6.0	9.0	12.0
3	10H	[1]10-H fuel moisture	[1-60%]	–		
4	100H	[1]100-H fuel moisture	[1-60%]	–		
5	HERB	[1]Live herb moisture	[30-300%]	–		
6	WOOD	[1]Live woody moisture	[30-300%]	–		
7	MFWS	Midflame windspeed	[0-99 mi/h]	8		
8	SLP	Slope	[0-100% or 0-45 degrees]	30%		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	20		
	PREDICT AT MAX		(Y/N)		N	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]	10	60	110
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h		See output table on next page.	
2	H/A	Heat per unit area	Btu/ft^2			
3	FLI	Fireline intensity	Btu/ft/s			
4	FL	Flame length	ft			
5	RI	Reaction intensity	Btu/ft^2/min			
6	EWS	Effective windspeed in direction SDIR	mi/h			
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees			

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 1c.—DIRECT input list for a range of three values for two inputs.

OUTPUT TABLES

LIST NUMBER 22d

TABLE NO. 6 TABLE ITEM: EWS ROW ITEM 1H COL. ITEM SDIR

Column Values: 10 60 110

Row No.	Row Value	Table Values		
1	6.0	7.3	2.2	0.6
2	9.0	7.3	2.2	0.6
3	12.0	7.3	2.2	0.6

TABLE NO. _____ TABLE ITEM: _____ ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1				
2				
3				

TABLE NO. _____ TABLE ITEM: _____ ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1				
2				
3				

Exhibit 1d.—Table of effective windspeed outputs for the range of three values for two inputs shown in exhibit 1c.

```
1   MODEL #          3          Ex. 1a
2   1H    6.0
7   MFWS  8
8   SLP   30
9   WDIR  20
10  SDIR             MAX

======================

1   ROS   228
2   H/A   742
3   FLI   3102
4   FL    18.2
5   RI    2900
6   EWS   8.4
7   MAXD  19

======================


1   MODEL #          3          Ex. 1b
2   1H    6.0   9.0   12.0
7   MFWS  8
8   SLP   30
9   WDIR  20
10  SDIR  10

======================
    1H    6.0   0.0   12.0
======================
1   ROS   189   155   136
2   H/A   742   673   648
3   FLI   2574  1912  1620
4   FL    16.7  14.5  13.5
5   RI    2900  2628  2532
6   EWS   7.3   7.3   7.3
======================


1   MODEL #          3          Ex. 1c
2   1H    6.0   9.0   12.0
7   MFWS  8
8   SLP   30
9   WDIR  20
10  SDIR  10    60    110

======================
   6   EWS    1H     *  SDIR
             10     60     110
======================
1:6.0     7.3   2.2   0.6      Ex. 1d
2:9.0     7.3   2.2   0.6
3:12.0    7.3   2.2   0.6
======================
```

Exhibit 1e.—Printer list for examples of DIRECT module.

The SIZE Module

The prompt "SIZE: I,L,R,MA,Q" indicates that you are in the SIZE module operating independently (not linked to DIRECT). The SIZE module provides estimates of the fire size, perimeter, length-to-width ratio, forward and backing spread distances, and maximum width at the end of a specified burning time. These estimates are for a fire originating from a point source, not a line source, and spreading at a constant rate through surface fuels during the elapsed time. The fire shape is assumed to be approximately elliptical. Exhibits 2a, 2b, and 2c illustrate typical runs in the SIZE module.

SIZE MODULE (English Units)

LIST NUMBER 23a

(Keywords: Input, List, Run, MAp, [1]COntain, Quit)

INPUT	(Input, List)					
1	ROS	[2]Rate of spread	[0.1-500 ch/h]	20.0		
2	EWS	[2]Effective windspeed	[0-99 mi/h]	8.0		
3	ET	Elapsed time	[0.1 - 8 h]	1.0	2.0	4.0
OUTPUT	(Run)					
0		No more tables				
1	AREA	Area	acres	11	44	178
2	PER	Perimeter	ch	46	92	183
3	L/W	Length-to-width ratio		3.0	3.0	3.0
4	FSD	Forward spread distance	ch	20.0	40.0	80.0
5	BSD	Backing spread distance	ch	0.6	1.2	2.4
6	MXW	Maximum fire width	ch	6.9	13.7	27.5

[1]SIZE can link to CONTAIN only if linked to DIRECT.
[2]Input only when SIZE is used as an independent module.

Exhibit 2a.—SIZE run obtaining a list of outputs for a range of elapsed burning time inputs.

SIZE MODULE (English Units)

LIST NUMBER 23b

(Keywords: Input, List, Run, MAp, [1]COntain, Quit)

INPUT	(Input, List)					
1	ROS	[2]Rate of spread	[0.1-500 ch/h]	5.0	10.0	20.0
2	EWS	[2]Effective windspeed	[0-99 mi/h]	8.0		
3	ET	Elapsed time	[0.1 - 8 h]	1.0	2.0	4.0
OUTPUT	(Run)					
0		No more tables				
1	AREA	Area	acres	see output table on next page.		
2	PER	Perimeter	ch			
3	L/W	Length-to-width ratio				
4	FSD	Forward spread distance	ch			
5	BSD	Backing spread distance	ch			
6	MXW	Maximum fire width	ch			

[1]SIZE can link to CONTAIN only if linked to DIRECT.
[2]Input only when SIZE is used as an independent module.

Exhibit 2b.—SIZE input list for generating a table of outputs.

OUTPUT TABLES

LIST NUMBER 23b

TABLE NO. 1 TABLE ITEM: AREA ROW ITEM ROS COL. ITEM ET

Column Values: 1.0 2.0 4.0

Row No.	Row Value	Table Values		
1	5.0	1	3	11
2	10.0	3	11	44
3	20.0	11	44	178

TABLE NO. 2 TABLE ITEM: PER ROW ITEM ROS COL. ITEM ET

Column Values: 1.0 2.0 4.0

Row No.	Row Value	Table Values		
1	5.0	11	23	46
2	10.0	23	46	92
3	20.0	46	92	183

TABLE NO. _____ TABLE ITEM: _____ ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1				
2				
3				

Exhibit 2c.—SIZE output tables of areas and perimeters calculated from the inputs in exhibit 2b.

The CONTAIN Module

The CONTAIN module is used to estimate fire suppression requirements, providing the following two run options for this purpose:

- Run option 1—estimate the total line-building rate required to contain the fire at a specific size, called the burned area target.
- Run option 2—estimate the final fire size, given a specific line-building capability.

Either run option permits the fire to be attacked at the head or the rear.

The results from CONTAIN are valid only within the basic assumptions that were used in developing the mathematical model. These are:

- The fire has an elliptical shape at the time of attack.
- The rate of spread is constant during the time required to construct the control line.
- The containment line is constructed at the edge of the fire.
- Work proceeds simultaneously on both sides of the fire at an equal pace.

CONTAIN MODULE (English Units)

LIST NUMBER 25a

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = calculate total line building rate 2 = calculate burned area	(1 or 2)		1	
2	ATTACK OPT	Attack option 1 = head 2 = rear	(1 or 2)		1	
3	ROS	[1]Rate of spread	[0.1-500 ch/h]	10.0	15.0	20.0
4	AREA	[1]Initial fire area	[0.1-100 acres]	5.0		
5	L/W	[1]Length-to-width ratio	[1-5]	3.0		
6	BAT	[2]Burned area target	[0.1-2000 acres]	7.0		
7	TLBR	[3]Total line-building rate	[0.1-800 ch/h]	—		
OUTPUT	(Run)					
1	PER	Total length of line	chains	35	35	35
2	TIME	Containment time	hours	1.0	0.7	0.5
3	FFS	[4]Final fire size	acres	—	—	—
3	TLBR	[5]Total line-building rate	ch/h	33	50	67
4	MAXA	[5]Maximum area calculable	acres	8	8	8
5	MINA	[5]Minimum area calculable	acres	5	5	5

Error Codes:

- −1 = Burned area target too large, cannot calculate slow enough line building rate
- −2 = Line building rate too slow to catch fire
- −3 = L/W ratio too large
- −4 = Burned area target too close to initial fire size
- −5 = Line building rate too fast

[1]Input only when CONTAIN is used as an independent module.
[2]Input only for run option = 1 (calculate total line-building rate).
[3]Input only for run option = 2 (calculate burned area target).
[4]Output only for run option = 2.
[5]Output only for run option = 1.

Exhibit 3a.—CONTAIN run obtaining a list of outputs using run option 1.

When calculating the final fire size, CONTAIN uses total line-building rate rather than line-building rate per flank as was used in the TI-59 program (Albini and Chase 1980). The program then applies half of the line-building rate to each flank. Thus the line-building rate entered must be more than twice the forward rate of spread; otherwise the control forces will never catch the fire.

When calculating the line-building rate required to contain the fire to a specific size, the target fire size must be larger than the initial fire size.

Calculator results from this module may differ somewhat from the BEHAVE outputs because the computational algorithm is different. To save computation time, the calculator results are based on a table lookup and interpolation process, whereas BEHAVE uses a pure computational method (Andrews and Morris in preparation). Because it is easy for the value of requested outputs to exceed the limits of the table in the calculator, the maximum (MAXA) and minimum (MINA) burned area targets calculable are output (Run option 1). Negative numbers (−1 to −5) indicate error codes as referenced on the data sheet. Exhibits 3a and 3b provide examples of calculating both total line-building rate and final fire size.

CONTAIN MODULE (English Units)

LIST NUMBER 25b

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = calculate total line building rate 2 = calculate burned area	(1 or 2)		2	
2	ATTACK OPT	Attack option 1 = head 2 = rear	(1 or 2)		2	
3	ROS	[1]Rate of spread	[0.1-500 ch/h]	10.0	15.0	20.0
4	AREA	[1]Initial fire area	[0.1-100 acres]	5.0		
5	L/W	[1]Length-to-width ratio	[1-5]	3.0		
6	BAT	[2]Burned area target	[0.1-2000 acres]	−		
7	TLBR	[3]Total line building rate	[0.1-800 ch/h]	60.0		
OUTPUT	(Run)					
1	PER	Total length of line	chains	47	62	94
2	TIME	Containment time	hours	0.8	1.0	1.6
3	FFS	[4]Final fire size	acres	10	15	30
3	TLBR	[5]Total line building rate	ch/h	−		
4	MAXA	[5]Maximum area calculable	acres	−		
5	MINA	[5]Minimum area calculable	acres	−		

Error Codes:

−1 = Burned area target too large, cannot calculate slow enough line building rate
−2 = Line building rate too slow to catch fire
−3 = L/W ratio too large
−4 = Burned area target too close to initial fire size
−5 = Line building rate too fast

[1]Input only when CONTAIN is used as an independent module.
[2]Input only for run option = 1 (calculate total line building rate).
[3]Input only for run option = 2 (calculate burned area target).
[4]Output only for run option = 2.
[5]Output only for run option = 1.

Exhibit 3b.—CONTAIN run obtaining a list of outputs using run option 2.

The SPOT Module

The SPOT module predicts the **maximum** spotting distance from three firebrand sources:

- torching trees
- burning piles
- wind-driven surface fires.

Although spot fires may occur at lesser distances, the purpose of this calculation is to estimate the greatest distance at which spot fires can be expected. The number of spot fires likely to occur is not estimated. None of the spotting calculations apply in the case of extreme fire behavior such as running crown fires, or any situation in which large fire whirls occur.

The wind-driven surface fire option applies only to fires occurring in surface fuels without timber cover and predicts only intermediate range spotting. Specifically, not included is short-range (a few tens of yards) spotting resulting from low intensity fires, or very long-range (several miles) spotting associated with extreme fire behavior such as crowning and large fire whirls.

Exhibits 4a, 4b, and 4c provide an example of inputs required for each of the three firebrand sources.

SPOT MODULE (English Units)

LIST NUMBER 26a

(Keywords: Input, List, Run, MAp, Quit)

INPUT	(Input, List)					
1	BRAND SRC	Firebrand source 1 = torching trees 2 = burning piles 3 = wind-driven surface fire	(1-3)		1	
2	MCHT	Mean cover height	[0-300 ft]	100		
3	20'W	20-ft windspeed	[0-99 mi/h]	10	20	40
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	1,500		
5	RVHD	Ridge-to-valley horiz. distance	[0-4 mi]	1.5		
6	SRC LOC	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop	(0-3)		3	
7	TREE SP	[1]Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir	(1-6)		2	
8	DBH	[1]Torching tree DBH	[5-40 inches]	20		
9	TRHT	[1]Torching tree height	[10-300 ft]	90		
10	#TR	[1]Number of torching trees	[1-30]	4		
11	FLHT	[2]Continuous flame height	[1-100 ft]	-		
12	FL	[3]Flame length	[0.1-50 ft]	-		
13	MODEL #	[3]Fuel model	(1-99)		-	
14	HERB	[4]Herbaceous moisture	[30-300%]	-		
OUTPUT	(Run)					
1	SPOT	Maximum spotting distance	mi	0.24	0.47	0.88

[1]Input only for firebrand source = 1 (torching tree option).
[2]Input only for firebrand source = 2 (burning pile option).
[3]Input only for firebrand source = 3 (wind-driven surface fire option).
[4]Input only for dynamic fuel models with a herbaceous fuel load.

Exhibit 4a.—SPOT run with torching trees as the firebrand source.

SPOT MODULE (English Units)

LIST NUMBER 266

(Keywords: Input, List, Run, MAp, Quit)

INPUT	(Input, List)					
1	BRAND SRC	Firebrand source 1 = torching trees 2 = burning piles 3 = wind-driven surface fire	(1-3)		2	
2	MCHT	Mean cover height	[0-300 ft]	100		
3	20'W	20-ft windspeed	[0-99 mi/h]	10	20	40
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	1,500		
5	RVHD	Ridge-to-valley horiz. distance	[0-4 mi]	1.5		
6	SRC LOC	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop	(0-3)		3	
7	TREE SP	[1]Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodge-pole pine 5 = white pine 6 = balsam fir, grand fir	(1-6)		-	
8	DBH	[1]Torching tree DBH	[5-40 inches]	-		
9	TRHT	[1]Torching tree height	[10-300 ft]	-		
10	#TR	[1]Number of torching trees	[1-30]	-		
11	FLHT	[2]Continuous flame height	[1-100 ft]	20		
12	FL	[3]Flame length	[0.1-50 ft]	-		
13	MODEL #	[3]Fuel model	(1-99)		-	
14	HERB	[4]Herbaceous moisture	[30-300%]	-		
OUTPUT	(Run)					
1	SPOT	Maximum spotting distance	mi	0.09	0.18	0.35

[1]Input only for firebrand source = 1 (torching tree option).
[2]Input only for firebrand source = 2 (burning pile option).
[3]Input only for firebrand source = 3 (wind-driven surface fire option).
[4]Input only for dynamic fuel models with a herbaceous fuel load.

Exhibit 4b.—SPOT run with burning piles as the firebrand source.

SPOT MODULE (English Units)

LIST NUMBER 26c

(Keywords: Input, List, Run, MAp, Quit)

INPUT	(Input, List)					
1	BRAND SRC	Firebrand source 1 = torching trees 2 = burning piles 3 = wind-driven surface fire	(1-3)		3	
2	MCHT	Mean cover height	[0-300 ft]	100		
3	20'W	20-ft windspeed	[0-99 mi/h]	10	20	40
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	1,500		
5	RVHD	Ridge-to-valley horiz. distance	[0-4 mi]	1.5		
6	SRC LOC	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop	(0-3)		3	
7	TREE SP	[1]Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir	(1-6)		–	
8	DBH	[1]Torching tree DBH	[5-40 inches]	–		
9	TRHT	[1]Torching tree height	[10-300 ft]	–		
10	#TR	[1]Number of torching trees	[1-30]	–		
11	FLHT	[2]Continuous flame height	[1-100 ft]	–		
12	FL	[3]Flame length	[0.1-50 ft]	20.0		
13	MODEL #	[3]Fuel model	(1-99)		4	
14	HERB	[4]Herbaceous moisture	[30-300%]	–		
OUTPUT	(Run)					
1	SPOT	Maximum spotting distance	mi	0.33	0.52	0.80

[1]Input only for firebrand source = 1 (torching tree option).
[2]Input only for firebrand source = 2 (burning pile option).
[3]Input only for firebrand source = 3 (wind-driven surface fire option).
[4]Input only for dynamic fuel models with a herbaceous fuel load.

Exhibit 4c.—SPOT run with a wind-driven surface fire as the firebrand source.

The SCORCH Module

The SCORCH module can be used to estimate the height to which tree crowns will be scorched by a surface fire burning beneath them. This module must be used with caution because very limited data were used for development of the mathematical scorch height model. Results may also be erroneous if applied to slopes steeper than 30 percent. Exhibit 5 shows a typical example of a SCORCH module run.

SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[33-120 °F]	90		
2	FL	[1]Flame length	[0.1-20 ft]	4.0		
3	MFWS	[1]Midflame windspeed	[0-10 mi/h]	0	5	10
OUTPUT	(Run)					
1	SCHT	Scorch height	feet	30	21	10

[1]Input only if SCORCH is used as an independent module.

TABLE NO. 1 TABLE ITEM: Scorch height ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value		Table Values	
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

Exhibit 5.—SCORCH run obtaining a list of scorch heights for a range of midflame windspeeds.

The IGNITE Module

The IGNITE module can be used to calculate the probability that a firebrand will ignite a fire if it lands on fine dead fuel. Probability is calculated to the nearest 10 percent and does not indicate whether or not the ignition will result in a sustained fire. The probability of ignition is not the same as the ignition component (IC) of the National Fire-Danger Rating System (NFDRS). The NFDRS-IC uses fire spread rate as well as probability of ignition to estimate the likelihood of a sustained fire on which suppression action may be required. The MOISTURE module discussed later also calculates ignition probability.

Exhibit 6 shows an example probability of ignition run.

IGNITE MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[33-120 °F]	90		
2	1H	1-h fuel moisture	[1-60%]	5.0	10.0	15.0
3	SHAD	Shade	[0-100%]	30		
OUTPUT	(Run)					
1	P(I)	Probability of ignition	pct	70	30	20

TABLE NO. 1 TABLE ITEM: Prob. of Ignition ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

Exhibit 6.—IGNITE run obtaining a list of ignition probabilities for a range of 1-hour fuel moistures.

The MOISTURE Module

The MOISTURE module is used to calculate the moisture content of fine dead fuels (Rothermel and others 1986). It has two run options:

- Run option 1.—Calculate the 1-hour fuel moisture, fuel level temperature and relative humidity, percent shade, and probability of ignition for a specific time. This is the burn time option.
- Run option 2.—Calculate the 1-hour fuel moisture and fuel level temperature and relative humidity each hour. This is the hourly option.

The input line numbers have been made to coincide with those used for the MOISTURE and SITE modules of the FIRE2 program of BEHAVE. Thus, missing input line numbers are for FIRE2 line numbers not used for the HP-71.

Although there are numerous inputs, many are not used for specific cases. For example, aspect is not requested if the slope is 0, timber overstory information is not requested if the crown closure is 0, sunset and sunrise weather are not asked if burn time is before sunset, and the various moisture initialization options request different inputs. These examples are not exhaustive, but the program will prompt for the data required for any specific run.

If you do not have estimates of the overstory tree characteristics and think you can estimate the amount of shade caused by the overstory, answer line 15 (crown closure) with 0 percent and line 25 (burn day cloud cover) with your estimate of shade for both the clouds and the overstory. This is recommended only for option 1.

Several input items are requested for the "burn day," which is defined to be the period from 1200 noon to 1200 noon, **not** from midnight to midnight. "Burn day −1" is the previous period from 1200 to 1200. The amount of weather input required depends on the time of day designated as "burn time."

Fuel moisture must be specified at 1400 on the day before the burn. BEHAVE offers five "Moisture Initialization Options" to assist in specifying this value, but the HP-71B calculator offers only four. Moisture initialization option 2 (complete data for the previous 7 days) is not allowed. Option 1 permits input of fine fuel moisture when it is known for the day before the burn; options 3, 4, and 5 are used when incomplete weather information is available.

Particular care must be exercised when changing the value of specific inputs by entering them individually. You may find that more input is required (the calculator displays "INCOMPLETE INPUTS") or that you are using invalid inputs left over from a previous run. While this is true with all modules, it is particularly true with this one, so always list and check your inputs before a RUN.

Examples of RUN OPTION 1 and RUN OPTION 2 are shown in exhibits 7a and 7b. The other inputs are the same for both cases. Enter the input values shown to get the burn time outputs. Then change the first input (RUN OPTION) to 2, and rerun to get the hourly output table. Multiple inputs are not allowed in the hourly option. The MOISTURE module takes longer to run as burn time approaches the end of the burn day or if multiple inputs are used, so some patience is required to obtain an answer in these cases. The output form for run option 2 has an extra line at the bottom to record burn time data that does not end on an even hour.

MOISTURE MODULE (English Units)

LIST NUMBER 30a-1

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = Burn time calculations 2 = Hourly calculations	(1 or 2)		1	
TIME AND LOCATION						
2	BURN MONTH	Month of burn	(1-12)		7	
3	BURN DAY	Day of burn	(1-31)		12	
4	LATITUDE	Latitude of fire location	(−90 to 90 degrees)		45	
5	BURN TIME	Time of burn	(0-2,359 h)		2,230	
FUEL MODEL						
6	MODEL #	Fuel model number	(1-99)		2	
SLOPE, ELEVATION, ASPECT						
11	SLP	Slope steepness	[0-100% or 0-45 degrees]	20		
12	ELFL	Elevation of fire location	[0-12,000 ft]	3,000		
	RH OBS AT FIRE		(Y/N)		Y	
13	ELOB	Elevation of T&RH observations	(0-12,000 ft)		-	
14	ASPECT	Aspect of fire location 0 = north 180 = south 90 = east 270 = west	(0-360 degrees)		270	
TIMBER OVERSTORY DESCRIPTION						
15	CCLO	Crown closure	[0-100%]	20		
16	FOLIAGE	Foliage presence 0 = absent 1 = present	(0 or 1)		1	
17	SHADE TOL	Shade tolerance 0 = intolerant 1 = tolerant	(0 or 1)		0	
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)		1	
19	AVHT	Average tree height	[10-300 ft]	80		
20	H/H	Crown height/tree height ratio	[0.1-1]	0.50		
21	H/D	Crown height/crown diameter ratio	[0.2-5]	3.00		

Exhibit 7a.—MOISTURE run obtaining just burn time outputs using run option 1.

MOISTURE MODULE (continued, English Units)

LIST NUMBER 30a-2

EARLY AFTERNOON WEATHER

22	14T	Burn day 1400 temperature	[33-120 °F]	80		
23	14RH	Burn day 1400 relative humidity	[1-100%]	20		
24	14W	Burn day 1400 20-ft windspeed	[0-99 mi/h]	10		
25	14CC	Burn day cloud cover	[0-100%]	20		
26	14HZ	Burn day 1400 haziness	[1-4]	2		

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

SUNSET WEATHER

27	SST	Sunset temperature	[33-120 °F]	70		
28	SSRH	Sunset relative humidity	[1-100%]	25		
29	SSW	Sunset 20-ft windspeed	[0-99 mi/h]	5		
30	SSCC	Sunset cloud cover	[0-100%]	20		

SUNRISE WEATHER

31	SRT	Sunrise temperature	[33-120 °F]	–		
32	SRRH	Sunrise relative humidity	[1-100%]	–		
33	SRW	Sunrise 20-ft windspeed	[0-99 mi/h]	–		
34	SRCC	Sunrise cloud cover	[0-100%]	–		

BURN TIME WEATHER

35	BTT	Burn time temperature	[33-120 °F]	65		
36	BTRH	Burn time relative humidity	[1-100%]	28		
37	BTW	Burn time 20-ft windspeed	[0-99 mi/h]	4		
38	BTCC	Burn time cloud cover	[0-100%]	–		
39	BTHZ	Burn time haziness	[1-4]	–		

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

Exhibit 7a. (Con.)

MOISTURE MODULE (continued, English Units)

LIST NUMBER 30a-3

BURN TIME WIND

40	EXPOSURE	Exposure of fuels to wind 1 = exposed 2 = partially sheltered 3 = fully sheltered—open stand 4 = fully sheltered—dense stand 5 = direct entry of wind adjustment factor	(1-5)	2
41	WAF	Wind adjustment factor Exposure 5 only	(0-1)	-

MOISTURE INITIALIZATION OPTION

43	MOIS OPT	Moisture initialization option 1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing	(1-5)	1

MOISTURE OPTION 1

44	FM-1	Burn day −1 fine fuel moisture	[1-100%]	10		

MOISTURE OPTION 3

51	RDAY	Number of days before burn that rain occurred	[1-7 days]	-		
52	RAIN	Rain amount, hundredths of an inch	[0-400]	-		
53	RDT	1400 temperature on rain day	[33-120 °F]	-		
54	SKY CODE	Sky condition from rain day to burn day 1 = clear 2 = cloudy 3 = partly cloudy	(1-3)		-	

MOISTURE OPTION 4

No additional input.

Exhibit 7a. (Con.)

MOISTURE MODULE (continued, English Units)

LIST NUMBER 30a-4

MOISTURE OPTION 5

55	TD-1	Burn day −1 1400 temperature	[33-120 °F]	—		
56	RD-1	Burn day −1 1400 relative humidity	[1-100%]	—		
57	WD-1	Burn day −1 1400 20-ft windspeed	[0-99]	—		
58	CD-1	Burn day −1 1400 cloud cover	[0-100%]	—		
59	WTHR	Weather condition prior to burn day −1 1 = hot and dry 2 = cool and wet 3 = between 1 and 2	[1-3]	—		

OUTPUT (Run)

1	MOIS	1-hour fuel moisture	pct	6.2		
2	TEMP	Fuel level temperature	°F	65		
3	%RH	Fuel level relative humidity	pct	28		
4	SHAD	Percent of area shaded	pct	100		
5	P(I)	Probability of ignition	pct	50		

Exhibit 7a. (Con.)

MOISTURE MODULE (continued, English Units)

LIST NUMBER 30b

HOURLY OUTPUT (Run)

TIME	FMOIST	FTEMP	FRH
	pct	°F	pct
14	6.1	88.7	15.0
15	5.8	86.8	16.0
16	5.7	83.4	17.7
17	5.7	79.0	20.0
18	5.7	74.6	22.6
19	5.8	71.6	24.2
20	5.9	69.3	25.4
21	6.1	67.5	26.5
22	6.2	65.8	27.5
23			
24			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
Burn Time 22.5	6.2	65.0	28.0

Exhibit 7b.—MOISTURE outputs using the inputs listed in exhibit 7a but with run option 2 to calculate hourly values.

The MAP Module

The MAP module permits calculation of fire spread distances, or spot distances, with the output expressed in units (inches or centimeters) to enable plotting the fire on a map. Inputs of scale option, representative fraction, and inches per mile are common to both MAP and SLOPE modules. In the metric option, only representative fraction is allowed for scale option. Exact output obtained depends on the UNITS OPTION selected and whether the run is independent or linked to other modules.

The example shown in exhibit 8 is for an independent MAP run. Note that unit option 2 (spot distance) requires an input in miles while other inputs are in chains. Also, unit option 3 (rate of spread) requires the elapsed time to make the distance calculation. The input and output characteristics of linked MAP runs vary considerably and will be discussed in a later section.

MAP MODULE (English Units)

LIST NUMBER 3/a

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	SCL OPT	Scale option 1 = Representative fraction 2 = Inches per mile	(1 or 2)	2		
2	RF/1000	[1]Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)	—		
3	IN/MI	[2]Inches per mile	(0.0625-8)	2.00		
4	UNITS OPT	Units option 1 = Spread distance 2 = Spot distance 3 = Rate of spread	(1-3)	3		
5	DIST	[3]Spread distance	[0-1000 ch]	—		
6	SPOT	[4]Spot distance	[0.1-10 mi]	—		
7	ROS	[5]Rate of spread	[0.1-500 ch/h]	20.0		
8	TIME	[5]Elapsed time	[0.1-8 h]	1.0	2.0	4.0
5	FSD	[6]Forward spread distance	ch	—		
6	BSD	[6]Backing spread distance	ch	—		
7	MXW	[6]Maximum fire width	ch	—		
OUTPUT	(Run)					
1	MFSD	Forward spread distance on map (UNITS OPT = 1 or 3)	inches	0.5	1.0	2.0
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	inches	—		
2	MBSD	Backing spread distance on map (SIZE linked only)	inches	—		
3	MMXW	Maximum fire width on map (SIZE linked only)	inches	—		

[1]Input only for scale option = 1.
[2]Input only for scale option = 2.
[3]Input only for units option = 1.
[4]Input only for units option = 2.
[5]Input only for units option = 3.
[6]Passed from SIZE for linked run only. No input is needed.

Exhibit 8.—MAP run obtaining a list of map distances for forward fire spread distances.

The SLOPE Module

The purpose of the SLOPE module is to provide a convenient means of calculating slope steepness, which you can then input to another module. Slope is output in both percentage and degrees, and does not depend on slope input units selected at the start of the BEHAVIOR program. All the inputs can be obtained from a good contour map. Inputs of scale option, representative fraction, and inches per mile are common to both SLOPE and MAP modules. In the metric option, only representative fraction is allowed for scale option. The heading "From Point ____ to ____ Point " on the worksheet is to provide a label that corresponds to similarly labeled points on a map. A typical slope calculation is shown in exhibit 9.

SLOPE MODULE (English Units)

LIST NUMBER 32a

(Keywords: Input, List, Run, Quit)

From Point A to Point B

INPUT	(Input, List)			
1	SCL OPT	Scale option 1 = Representative fraction 2 = Inches per mile	(1 or 2)	2
2	RF/1000	[1]Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)	—
3	IN/MI	[2]Inches per mile	(0.0625-8 in)	2.00
4	CON INT	Contour interval	(10-500 ft)	200
5	MAP DIST	Map distance	(0.1-10 in)	1.0
6	# INTVLS	Number of contour intervals	(1-100)	3
OUTPUT	(Run)			
1	SLP %	Slope steepness	pct	23
2	SLP DEG	Slope steepness	degrees	13
3	EL DIFF	Elevation change	feet	600
4	HORIZ DIST	Horizontal distance	feet	2640

[1]Input only for scale option = 1.
[2]Input only for scale option = 2.

Exhibit 9.—SLOPE run example.

The WIND Module

The WIND adjustment module is used independently to adjust the windspeed, as measured 20 feet above the vegetation, to a windspeed at midflame height. In the metric version, the program assumes the 20-foot windspeed equals the 10-meter windspeed. The midflame windspeed can then be entered manually in other modules. Four wind exposure options are available for various amounts of sheltering, plus a fifth option to enter the wind adjustment factor directly. The adjustment factor for exposed fuels depends on the fuel model; the adjustment factors for sheltered and partially sheltered fuels do not. A typical midflame windspeed calculation is shown in exhibit 10.

WIND ADJUSTMENT MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	20'W	20-ft windspeed	[0-99 mi/h]	5	10	15
2	EXPOSURE	Exposure to wind 1 = exposed 2 = partially sheltered 3 = fully sheltered, open stand 4 = fully sheltered, closed stand 5 = enter wind adjustment factor	(1-5)		1	
3	WAF	[1]Wind adjustment factor	(0-1)		–	
4	MODEL #	[2]Fuel model number	(1-99)		2	
OUTPUT	(Run)					
1	MFWS	Midflame windspeed	mi/h	2.0	4.0	6.0

[1]Input only for exposure = 5.
[2]Input only for exposure = 1.

Exhibit 10.—WIND run example.

The RH Module

The RH module is used to calculate relative humidity and dew point from dry and wet bulb temperatures, and elevation. The output RH is not automatically passed to other modules, but it can be entered manually. The RH calculations assume ice is present on the wet bulb if the temperature is below 32 °F (0 °C). Dew points below freezing are with respect to liquid water. An error will be generated if you enter a wet bulb temperature greater than the dry bulb temperature or if the dew point temperature is unrealistically low (below −40 °F or −40 °C). A typical humidity calculation is shown in exhibit 11.

RH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	DRYB	Dry bulb temperature	[33-120 °F]	80	85	90
2	WETB	Wet bulb temperature	[0-120 °F]	70	68	66
3	EL	Elevation	[0-12,000 ft]	5,000		
OUTPUT	(Run)					
1	%RH	Relative humidity	pct			
2	DEWP	Dew point	°F			

ERROR CODES:

−888 = Wet bulb temperature greater than dry bulb temperature

−999 = Dew point too cold for valid calculations

TABLE NO. 1 TABLE ITEM: %RH ROW ITEM DRYB COL. ITEM WETB

Column Values: 70 68 66

Row No.	Row Value	Table Values		
1	80	63	56	50
2	85	49	44	39
3	90	39	34	30

TABLE NO. 2 TABLE ITEM: DEWP ROW ITEM DRYB COL. ITEM WETB

Column Values: 70 68 66

Row No.	Row Value	Table Values		
1	80	66	63	60
2	85	64	61	57
3	90	62	58	54

Exhibit 11.—RH run obtaining tables of humidity and dew point.

OPERATING THE MODULES IN "LINKED" RUNS

"Linked" runs provide the capability to use results from one program module in another program module. Level 2 or 3 modules may be linked to specific level 1 or 2 modules, respectively, as shown in figure 1. Thus SIZE, SCORCH, MAP, and TWO may be linked to DIRECT, while MAP and CONTAIN may be linked to SIZE. MAP may also be linked to SIZE or SPOT when they are run independently.

Remember that multiple values may be entered for a maximum of two input items, including those passed from a linked module. Depending on the number of items for which multiple values are entered, you may pass to the "linked" module:

- a single value for each output item—one value entered for each input item,
- a list of values for each output item—two or three values entered for one input item,
- a table of values for each output item—two or three values entered for each of two input items.

If a set of single output values is passed forward, a list can be produced from the linked module by entering two or three values for one of the linked module inputs. A table would be produced by the linked module if multiple values were entered for two of the linked module inputs. If a list is passed forward to a linked module, a table may be produced by entering two or three values for one linked module input. If a table is passed forward, multiple values may not be entered for any linked module input.

Output produced by running a module independently will not be passed to another module that is also run independently. For example, if you run the DIRECT module from the MAIN program, then also run the SIZE module from MAIN after quitting DIRECT; the outputs from DIRECT will not be passed to SIZE. This would have to be accomplished by first running DIRECT, then selecting the SIZE module while you are still in the DIRECT module. SIZE output could similarly be passed to MAP or CONTAIN by selecting one of these modules while still in the SIZE module. In addition, you can link to another module only after a successful run using the module you are currently in. Otherwise, the display will briefly show the error message, "NO LINK BEFORE RUN". If any inputs are changed, a new run is necessary.

Linked run forms were considered, but found to be complicated and numerous if they were to be made for all possible combinations. Use the forms for individual modules. If multiple values are entered for one input item, the linked module will list the multiple output values. If a table is passed from one module to the next, then listing the inputs in the linked module will display the range of table values passed. The form of the display is: "ITEM LABEL value TO value". For example, "AREA 65 TO 303". Use the space provided for multiple inputs of this item to write this range on the data sheet for the linked module.

Linked DIRECT-SIZE-CONTAIN Run

An example DIRECT-SIZE-CONTAIN run is shown in exhibits 12a, 12b, and 12c. The rate of spread and effective windspeed, in the direction of maximum spread rate, are passed to SIZE. ROS and EWS passed to SIZE or CONTAIN are always in the direction of maximum spread rate. The ROS and EWS in the output list of DIRECT can be in other directions if that option was selected for input item 10 (SDIR) of DIRECT. Thus, outputs from linked SIZE or CONTAIN runs are independent of the spread direction input in DIRECT. The output from DIRECT is a list of three values for each output item. This is expanded to tabular output by entering three elapsed time (ET) values in SIZE, shown in exhibit 12b. Only single values can be entered in CONTAIN (exhibit 12c) because tables of AREA and L/W were passed to it from SIZE. That is, only one total line-building rate (TLBR) could be entered.

The AREA table produced by SIZE in exhibit 12b shows the size of the fire (acres) if it were to burn unconstrained for the nine combinations of three 1-hour fuel moistures (10, 11, and 12 percent) and three time intervals (1.0, 1.5, and 2.0 hours). These areas become the initial fire area for CONTAIN in exhibit 12c. Note that the SIZE module prompt "SIZE: I,L,R,MA,CO,Q" now gives you the option to go to CONTAIN. This option is only available in linked runs and not available in independent runs.

The final fire size (FFS) table produced by CONTAIN in exhibit 12c shows the size of the fire (acres) for the same nine combinations of 1-hour fuel moisture and burning time, but with suppression action being taken by forces attacking the fire from the rear. These forces have a total line construction rate capability of 100 chains per hour. The TIME table of CONTAIN shows how long it will take to contain the fire at the sizes listed in the FFS table.

DIRECT MODULE (English Units)

LIST NUMBER 37a

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		3	
2	1H	1-H fuel moisture	[1-60%]	10.0	11.0	12.0
3	10H	[1]10-H fuel moisture	[1-60%]	—		
4	100H	[1]100-H fuel moisture	[1-60%]	—		
5	HERB	[1]Live herb moisture	[30-300%]	—		
6	WOOD	[1]Live woody moisture	[30-300%]	—		
7	MFWS	Midflame windspeed	[0-99 mi/h]	2		
8	SLP	Slope	[0-100%/ 0-45 degrees]	20%		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	0		
	PREDICT AT MAX		(Y/N)		Y	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]			MAX
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	35	34	32
2	H/A	Heat per unit area	Btu/ft^2	662	654	648
3	FLI	Fireline intensity	Btu/ft/s	427	404	385
4	FL	Flame length	ft	7.3	7.1	7.0
5	RI	Reaction intensity	Btu/ft^2/min	2,585	2,555	2,532
6	EWS	Effective windspeed in direction SDIR	mi/h	2.3	2.3	2.3
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	0	0	0

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 12a.—DIRECT run obtaining outputs that can be linked to SIZE.

SIZE MODULE (English Units)

LIST NUMBER 37b

(Keywords: Input, List, Run, MAp, [1]COntain, Quit)

INPUT	(Input, List)					
1	ROS	[2]Rate of spread	[0.1-500 ch/h]	35	34	32
2	EWS	[2]Effective windspeed	[0-99 mi/h]	2.3	2.3	2.3
3	ET	Elapsed time	[0.1 - 8 h]	1.0	1.5	2.0
OUTPUT	(Run)					
0		No more tables				
1	AREA	Area	acres	see output table on next page.		
2	PER	Perimeter	ch			
3	L/W	Length-to-width ratio				
4	FSD	Forward spread distance	ch			
5	BSD	Backing spread distance	ch			
6	MXW	Maximum fire width	ch			

[1]SIZE can link to CONTAIN only if linked to DIRECT.
[2]Input only when SIZE is used as an independent module.

Exhibit 12b.—Linked SIZE run using DIRECT outputs shown in exhibit 12a.

OUTPUT TABLES

LIST NUMBER 376

TABLE NO. 1 TABLE ITEM: AREA ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	79	177	316
2	11.0	73	163	290
3	12.0	67	151	268

TABLE NO. 2 TABLE ITEM: PER ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	103	155	207
2	11.0	99	149	198
3	12.0	95	143	191

TABLE NO. 3 TABLE ITEM: L/W ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	1.6	1.6	1.6
2	11.0	1.6	1.6	1.6
3	12.0	1.6	1.6	1.6

Exhibit 12b. (Con.)

CONTAIN MODULE (English Units)

LIST NUMBER 37c

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = calculate total line building rate 2 = calculate burned area	(1 or 2)	2		
2	ATTACK OPT	Attack option 1 = head 2 = rear	(1 or 2)	2		
3	ROS	[1]Rate of spread	[0.1-500 ch/h]	35	34	32
4	AREA	[1]Initial fire area	[0.1-100 acres]	67	to	316
5	L/W	[1]Length-to-width ratio	[1-5]	1.6	to	1.6
6	BAT	[2]Burned area target	[0.1-2000 acres]	–		
7	TLBR	[3]Total line building rate	[0.1-800 ch/h]	100.0		
OUTPUT	(Run)					
1	PER	Total length of line	chains	See output tables on next page.		
2	TIME	Containment time	hours			
3	FFS	[4]Final fire size	acres			
3	TLBR	[5]Total line building rate	ch/h			
4	MAXA	[5]Maximum area calculable	acres			
5	MINA	[5]Minimum area calculable	acres			

Error Codes:

–1 = Burned area target too large, cannot calculate slow enough line building rate
–2 = Line building rate too slow to catch fire
–3 = L/W ratio too large
–4 = Burned area target too close to initial fire size
–5 = Line building rate too fast

[1]Input only when CONTAIN is used as an independent module.
[2]Input only for run option = 1 (calculate total line building rate).
[3]Input only for run option = 2 (calculate burned area target).
[4]Output only for run option = 2.
[5]Output only for run option = 1.

Exhibit 12c.—Linked CONTAIN run using outputs from DIRECT and SIZE.

OUTPUT TABLES

LIST NUMBER 37c

TABLE NO. 1 TABLE ITEM: PER ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	385	578	771
2	11.0	334	501	668
3	12.0	296	444	592

TABLE NO. 2 TABLE ITEM: TIME ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	3.9	5.8	7.7
2	11.0	3.3	5.0	6.7
3	12.0	3.0	4.4	5.9

TABLE NO. 3 TABLE ITEM: FFS ROW ITEM 1H COL. ITEM ET

Column Values: 1.0 1.5 2.0

Row No.	Row Value	Table Values		
1	10.0	773	1,740	3,093
2	11.0	600	1,351	2,402
3	12.0	484	1,090	1,937

Exhibit 12c. (Con.)

SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[33-120 °F]	80		
2	FL	[1]Flame length	[0.1-20 ft]	7.3	7.1	7.0
3	MFWS	[1]Midflame windspeed	[0-10 mi/h]	2		
OUTPUT	(Run)					
1	SCHT	Scorch height	feet	59	57	55

[1]Input only if SCORCH is used as an independent module.

TABLE NO. 1 TABLE ITEM: Scorch height ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value		Table Values	
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

Exhibit 13.—Linked SCORCH run obtaining a list of scorch heights from the DIRECT outputs of exhibit 12a.

Linked DIRECT-SCORCH Run

The DIRECT run in the previous example (exhibit 12a) can be linked to SCORCH by entering SC after a valid DIRECT run. The midflame windspeed and flame length in the direction of spread selected by SDIR are passed to SCORCH. Only air temperature needs to be input for SCORCH calculations. The calculations are not corrected for slope; erroneous results may be obtained for slopes steeper than 30 percent. The output of SCORCH linked to DIRECT is shown in exhibit 13.

Linked DIRECT-TWO Run

The TWO module is available only by linking to it through DIRECT. This module is used to weight the spread rate of fire through two very different fuel types that occur as interspersed patches in the same general area.

First, run DIRECT with the fuel model and environmental conditions that describe the situation for one of the vegetation types. Then do a second run for the other fuel model. Except for model number, all other DIRECT inputs common to both models should be equal for both runs. If the second model requires additional moisture inputs for additional fuel classes, these inputs should be made. DIRECT must produce single output, list output, or tabular output for **both** models. That is, you cannot link to TWO if you have, for example, produced a list output with the first model and a tabular output with the second. This will produce the message "INPUT ERROR".

After doing both DIRECT runs, enter keyword TW to link to the TWO module. A List at this point will produce a list of five items, the first four of which were values passed to TWO by DIRECT. Items 1 and 2 (MODEL1 and MODEL2, respectively) display the numbers of the fuel models used in the first and second DIRECT runs. Items 3 and 4 list the spread rates produced by the first and second models run by DIRECT. Spread rates are for the direction selected for the calculation in input item 10 (SDIR) of DIRECT.

The spread rates will be presented as single values, lists, or a range of values, depending on how many DIRECT input items were assigned multiple values. All of TWO items 1-4 are passed by DIRECT; you cannot enter any of them independently. You must, however, enter values for input item 5 — COV1. This is the percentage of area covered by the first fuel model run in DIRECT (item MODEL1). No input is needed for area coverage of the second model, as it is assumed to cover the remainder of the area.

The rate of spread calculated by TWO is not passed back to DIRECT, nor can it be used in SIZE or CONTAIN calculations. Once a Run is made in TWO, a

return to DIRECT will not allow subsequent links to other modules until a valid DIRECT Run is made.

An example follows in which two fuel models are run in DIRECT to produce two lists of spread rates (exhibits 14a and 14b). After the second Run a link is made to TWO as shown in exhibit 14c. Both fuel model numbers and the ROS output from DIRECT are passed to TWO. Only input 5, the area coverage (percent) of the first model (COV1), is needed to complete the input list in TWO. Three percentages of coverage were entered and a table of weighted ROS is output, as shown in the TWO data sheet.

DIRECT MODULE (English Units)

LIST NUMBER 40a

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		1	
2	1H	1-H fuel moisture	[1-60%]	8.0	10.0	12.0
3	10H	[1]10-H fuel moisture	[1-60%]	-		
4	100H	[1]100-H fuel moisture	[1-60%]	-		
5	HERB	[1]Live herb moisture	[30-300%]	-		
6	WOOD	[1]Live woody moisture	[30-300%]	-		
7	MFWS	Midflame windspeed	[0-99 mi/h]	4		
8	SLP	Slope	[0-100%/ 0-45 degrees]	20%		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	0		
	PREDICT AT MAX		(Y/N)		Y	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]			MAX
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	58	39	0
2	H/A	Heat per unit area	Btu/ft^2	84	59	0
3	FLI	Fireline intensity	Btu/ft/s	90	42	0
4	FL	Flame length	ft	3.6	2.5	0
5	RI	Reaction intensity	Btu/ft^2/min	764	538	0
6	EWS	Effective windspeed in direction SDIR	mi/h	4.2	4.2	0
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	0	0	0

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 14a.—First DIRECT run for linking to TWO in exhibit 14c.

DIRECT MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		4	
2	1H	1-H fuel moisture	[1-60%]	8.0	10.0	12.0
3	10H	[1]10-H fuel moisture	[1-60%]	10.0		
4	100H	[1]100-H fuel moisture	[1-60%]	12.0		
5	HERB	[1]Live herb moisture	[30-300%]	-		
6	WOOD	[1]Live woody moisture	[30-300%]	90		
7	MFWS	Midflame windspeed	[0-99 mi/h]	4		
8	SLP	Slope	[0-100%/ 0-45 degrees]	20		
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	0		
	PREDICT AT MAX		(Y/N)		Y	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]			MAX
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	61	59	56
2	H/A	Heat per unit area	Btu/ft^2	2,527	2,467	2,405
3	FLI	Fireline intensity	Btu/ft/s	2,846	2,667	2,490
4	FL	Flame length	ft	17.5	17.0	16.4
5	RI	Reaction intensity	Btu/ft^2/min	11,445	11,175	10,893
6	EWS	Effective windspeed in direction SDIR	mi/h	4.2	4.2	4.2
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	0	0	0

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

Exhibit 14b.—Second DIRECT run for linking to TWO in exhibit 14c.

TWO MODULE (English Units)

(Keywords: Input, List, Run, Quit)

PASSED FROM DIRECT (List)

1	MODEL1	First model run by DIRECT			1	
2	MODEL2	Second model run by DIRECT			4	
3	ROS1	Spread rate for first model		58	39	0
4	ROS2	Spread rate for second model		61	59	56

INPUT (Input, List)

5	COV1	Percent area coverage first model	[20-80%]	30	50	70

OUTPUT (Run)

1	ROS	Rate of spread	ch/h			

TABLE NO. 1 TABLE ITEM: Weighted ROS ROW ITEM IH COL. ITEM COV1

Column Values: 30 50 70

Row No.	Row Value	Table Values		
1	8.0	61	60	59
2	10.0	53	49	45
3	12.0	40	28	17

Exhibit 14c.—Linked TWO run using spread rates calculated for two models in exhibits 14a and 14b.

Linked MAP Runs

Linking to MAP from SIZE, SPOT, and DIRECT results in automatic selection of the MAP units option 1, 2, and 3, respectively. SIZE passes three distances to MAP—forward spread distance, backing spread distance, and maximum fire width. These three distances change the input item names on the independent MAP input sheets, and result in the three output map distances. SPOT passes a maximum spotting distance in miles. DIRECT passes a rate of spread to MAP where spread time is needed for MAP to calculate forward spread distance. Exhibits 15, 16, and 17 show examples of these different linked runs. A printer was used as a list device, but if no printer is attached, the same output can be seen on the display by stepping through the lists.

```
1   ROS     40.0    60.0    80.0
2   EWS      5.0                    } SIZE  List
3   ET       2.0

============================

    ROS     40.0    60.0    80.0

============================

1   AREA    249      559     995
2   PER     199      298     397    } SIZE  Run
3   L/W      2.3      2.3     2.3
4   FSD     80.0    120.0   160.0
5   BSD      4.4      6.6     8.8
6   MXW     37.5     56.3    75.0

============================

1   SCL OPT             2
3   IN/MI               1.000
4   UNITS OPT           1
5   FSD     80.0    120.0   160.0  } MAP  List
6   BSD      4.4      6.6     8.8
7   MXW     37.5     56.3    75.0

============================

    ROS     40.0    60.0    80.0

============================

1   MFSD     1.0      1.5     2.0   } MAP  Run
2   MBSD     0.0      0.0     0.1
3   MMXW     0.5      0.7     0.9

============================
```

Exhibit 15.—Example of SIZE run followed by link to MAP.

```
 1   BRAND SRC          1
 2   MCHT  100
 3   20'W  10       15        20
 4   RVEL  1000
 5   RVHD  1.0                     } SPOT  List
 6   SRC LOC            1
 7   TREE SP            1
 8   DBH   20
 9   TRHT  80
10   #TR   10

============================

      20'W  10       15        20

============================

 1   SPOT   0.26    0.39    0.53   } SPOT  Run

============================

 1   SCL OPT             2
 3   IN/MI               2.000
 4   UNITS OPT           2          } MAP  List
 6   SPOT   0.26    0.39    0.53

============================

      20'W  10       15        20

============================

 1   MSPT   0.51    0.78    1.05   } MAP  Run

============================
```

Exhibit 16.—Example of SPOT run followed by link to MAP.

```
 1    MODEL #          2
 2    1H       8.0
 3    10H     10.0
 4    100H    12.0
 5    HERB    80
 7    MFWS     5      7      10
 8    SLP     10
 9    WDIR    90
10    SDIR                   MAX
```

DIRECT List

```
==========================

      MFWS    5      7      10

==========================

 1    ROS     35     62     118
 2    H/A    463    463     463
 3    FLI    294    529     999
 4    FL     6.2    8.1    10.8
 5    RI    3357   3357    3357
 6    EWS    5.0    7.0    10.0
 7    MAXD   89     89      90

==========================
```

DIRECT Run

```
 1    SCL OPT          2
 3    IN/MI            1.000
 4    UNITS OPT        3
 7    ROS    35    62      118
 8    TIME   2.0

==========================

      MFWS   5      7      10

==========================

 1    MFSD   0.9    1.6    2.9

==========================
```

MAP List

MAP Run

Exhibit 17.—Example of DIRECT run followed by link to MAP.

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APPENDIX A: DATA SHEETS, ENGLISH UNITS OF MEASURE

FUEL MODEL MODULE (English Units)

(Keywords: Get, Input, List, Save, Quit, List Models, Delete Models)

INPUT LIST (Input, List)

1	MODEL #	Fuel model number	(14 - 99)	_____
2	NAME	Fuel model name	(22 char. max.)	_____
3	1HR LOAD	1-hour load	(0.01-30 tons/acre)	_____
4	10HR LOAD	10-hour load	(0-30 tons/acre)	_____
5	100HR LOAD	100-hour load	(0-30 tons/acre)	_____
6	HERB LOAD	Live herb load	(0-30 tons/acre)	_____
7	WOOD LOAD	Live woody load	(0-30 tons/acre)	_____
8	1HR S/V	1-hour surface/volume ratio	(1,200-3,500 ft^2/ft^3)	_____
9	HERB S/V	[1]Herb surface/volume ratio	(1,200-3,500 ft^2/ft^3)	_____
10	WOOD S/V	[2]Woody surface/volume ratio	(1,200-3,500 ft^2/ft^3)	_____
11	DEPTH	Fuel bed depth	(0.1 - 10 ft)	_____
12	HEAT	Fuel heat content	(7,000-12,000 Btu/lb)	_____
13	MOIS EXT	Dead fuel extinction moisture	(10 - 50%)	_____
14	STATIC-DYNAM	Static or dynamic model	(0 or 1)	_____
		0 = static or herb load is zero		
		1 = dynamic		
15	WIND FACTOR	Exposed fuel wind adjustment factor	(0.01 - 1)	_____

[1]Input only if herb load is greater than zero.
[2]Input only if wood load is greater than zero.

USER FUEL MODEL FILE CONTENTS (List Models)

Model Number	Model Name (22 characters maximum)

DIRECT MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		_____	
2	1H	1-H fuel moisture	[1-60%]	_____	_____	_____
3	10H	[1]10-H fuel moisture	[1-60%]	_____	_____	_____
4	100H	[1]100-H fuel moisture	[1-60%]	_____	_____	_____
5	HERB	[1]Live herb moisture	[30-300%]	_____	_____	_____
6	WOOD	[1]Live woody moisture	[30-300%]	_____	_____	_____
7	MFWS	Midflame windspeed	[0-99 mi/h]	_____	_____	_____
8	SLP	Slope	[0-100% or 0-45 degrees]	_____	_____	_____
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	_____	_____	_____
	PREDICT AT MAX		(Y/N)		_____	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]	_____	_____	_____
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	ch/h	_____	_____	_____
2	H/A	Heat per unit area	Btu/ft^2	_____	_____	_____
3	FLI	Fireline intensity	Btu/ft/s	_____	_____	_____
4	FL	Flame length	ft	_____	_____	_____
5	RI	Reaction intensity	Btu/ft^2/min	_____	_____	_____
6	EWS	Effective windspeed in direction SDIR	mi/h	_____	_____	_____
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	_____	_____	_____

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

SIZE MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, MAp, [1]COntain, Quit)

INPUT	(Input, List)					
1	ROS	[2]Rate of spread	[0.1-500 ch/h]	_____	_____	_____
2	EWS	[2]Effective windspeed	[0-99 mi/h]	_____	_____	_____
3	ET	Elapsed time	[0.1 - 8 h]	_____	_____	_____
OUTPUT	(Run)					
0		No more tables				
1	AREA	Area	acres	_____	_____	_____
2	PER	Perimeter	ch	_____	_____	_____
3	L/W	Length-to-width ratio		_____	_____	_____
4	FSD	Forward spread distance	ch	_____	_____	_____
5	BSD	Backing spread distance	ch	_____	_____	_____
6	MXW	Maximum fire width	ch	_____	_____	_____

[1]SIZE can link to CONTAIN only if linked to DIRECT.
[2]Input only when SIZE is used as an independent module.

CONTAIN MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = calculate total line building rate 2 = calculate burned area	(1 or 2)			
2	ATTACK OPT	Attack option 1 = head 2 = rear	(1 or 2)			
3	ROS	[1]Rate of spread	[0.1-500 ch/h]	_____	_____	_____
4	AREA	[1]Initial fire area	[0.1-100 acres]	_____	_____	_____
5	L/W	[1]Length-to-width ratio	[1-5]	_____	_____	_____
6	BAT	[2]Burned area target	[0.1-2000 acres]	_____	_____	_____
7	TLBR	[3]Total line building rate	[0.1-800 ch/h]	_____	_____	_____
OUTPUT	(Run)					
1	PER	Total length of line	chains	_____	_____	_____
2	TIME	Containment time	hours	_____	_____	_____
3	FFS	[4]Final fire size	acres	_____	_____	_____
3	TLBR	[5]Total line building rate	ch/h	_____	_____	_____
4	MAXA	[5]Maximum area calculable	acres	_____	_____	_____
5	MINA	[5]Minimum area calculable	acres	_____	_____	_____

Error Codes:

- −1 = Burned area target too large, cannot calculate slow enough line building rate
- −2 = Line building rate too slow to catch fire
- −3 = L/W ratio too large
- −4 = Burned area target too close to initial fire size
- −5 = Line building rate too fast

[1]Input only when CONTAIN is used as an independent module.
[2]Input only for run option = 1 (calculate total line building rate).
[3]Input only for run option = 2 (calculate burned area target).
[4]Output only for run option = 2.
[5]Output only for run option = 1.

SPOT MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, MAp, Quit)

INPUT	(Input, List)					
1	BRAND SRC	Firebrand source 1 = torching trees 2 = burning piles 3 = wind-driven surface fire	(1-3)			_____
2	MCHT	Mean cover height	[0-300 ft]	_____	_____	_____
3	20'W	20-ft windspeed	[0-99 mi/h]	_____	_____	_____
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	_____	_____	_____
5	RVHD	Ridge-to-valley horiz. distance	[0-4 mi]	_____	_____	_____
6	SRC LOC	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop	(0-3)			_____
7	TREE SP	[1]Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir	(1-6)			_____
8	DBH	[1]Torching tree DBH	[5-40 inches]	_____	_____	_____
9	TRHT	[1]Torching tree height	[10-300 ft]	_____	_____	_____
10	#TR	[1]Number of torching trees	[1-30]	_____	_____	_____
11	FLHT	[2]Continuous flame height	[1-100 ft]	_____	_____	_____
12	FL	[3]Flame length	[0.1-50 ft]	_____	_____	_____
13	MODEL #	[3]Fuel model	(1-99)			_____
14	HERB	[4]Herbaceous moisture	[30-300%]	_____	_____	_____
OUTPUT	(Run)					
1	SPOT	Maximum spotting distance	mi	_____	_____	_____

[1]Input only for firebrand source = 1 (torching tree option).
[2]Input only for firebrand source = 2 (burning pile option).
[3]Input only for firebrand source = 3 (wind-driven surface fire option).
[4]Input only for dynamic fuel models with a herbaceous fuel load.

SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[33-120 °F]	_____	_____	_____
2	FL	[1]Flame length	[0.1-20 ft]	_____	_____	_____
3	MFWS	[1]Midflame windspeed	[0-10 mi/h]	_____	_____	_____
OUTPUT	(Run)					
1	SCHT	Scorch height	feet	_____	_____	_____

[1]Input only if SCORCH is used as an independent module.

TABLE NO. 1 TABLE ITEM: Scorch height ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

IGNITE MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[33-120 °F]	_____	_____	_____
2	1H	1-h fuel moisture	[1-60%]	_____	_____	_____
3	SHAD	Shade	[0-100%]	_____	_____	_____
OUTPUT	(Run)					
1	P(I)	Probability of ignition	pct	_____	_____	_____

TABLE NO. 1 TABLE ITEM: Prob. of Ignition ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

APPENDIX A: (Con.)

MOISTURE MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = Burn time calculations 2 = Hourly calculations	(1 or 2)			
TIME AND LOCATION						
2	BURN MONTH	Month of burn	(1-12)			
3	BURN DAY	Day of burn	(1-31)			
4	LATITUDE	Latitude of fire location	(−90 to 90 degrees)			
5	BURN TIME	Time of burn	(0-2,359 h)			
FUEL MODEL						
6	MODEL #	Fuel model number	(1-99)			
SLOPE, ELEVATION, ASPECT						
11	SLP	Slope steepness	[0-100% or 0-45 degrees]			
12	ELFL	Elevation of fire location	[0-12,000 ft]			
	RH OBS AT FIRE		(Y/N)			
13	ELOB	Elevation of T&RH observations	(0-12,000 ft)			
14	ASPECT	Aspect of fire location 0 = north 180 = south 90 = east 270 = west	(0-360 degrees)			
TIMBER OVERSTORY DESCRIPTION						
15	CCLO	Crown closure	[0-100%]			
16	FOLIAGE	Foliage presence 0 = absent 1 = present	(0 or 1)			
17	SHADE TOL	Shade tolerance 0 = intolerant 1 = tolerant	(0 or 1)			
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)			
19	AVHT	Average tree height	[10-300 ft]			
20	H/H	Crown height/tree height ratio	[0.1-1]			
21	H/D	Crown height/crown diameter ratio	[0.2-5]			

MOISTURE MODULE (continued, English Units)

LIST NUMBER _____

EARLY AFTERNOON WEATHER

22	14T	Burn day 1400 temperature	[33-120 °F]	_____	_____	_____
23	14RH	Burn day 1400 relative humidity	[1-100%]	_____	_____	_____
24	14W	Burn day 1400 20-ft windspeed	[0-99 mi/h]	_____	_____	_____
25	14CC	Burn day cloud cover	[0-100%]	_____	_____	_____
26	14HZ	Burn day 1400 haziness	[1-4]	_____	_____	_____

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

SUNSET WEATHER

27	SST	Sunset temperature	[33-120 °F]	_____	_____	_____
28	SSRH	Sunset relative numidity	[1-100%]	_____	_____	_____
29	SSW	Sunset 20-ft windspeed	[0-99 mi/h]	_____	_____	_____
30	SSCC	Sunset cloud cover	[0-100%]	_____	_____	_____

SUNRISE WEATHER

31	SRT	Sunrise temperature	[33-120 °F]	_____	_____	_____
32	SRRH	Sunrise relative humidity	[1-100%]	_____	_____	_____
33	SRW	Sunrise 20-ft windspeed	[0-99 mi/h]	_____	_____	_____
34	SRCC	Sunrise cloud cover	[0-100%]	_____	_____	_____

BURN TIME WEATHER

35	BTT	Burn time temperature	[33-120 °F]	_____	_____	_____
36	BTRH	Burn time relative humidity	[1-100%]	_____	_____	_____
37	BTW	Burn time 20-ft windspeed	[0-99 mi/h]	_____	_____	_____
38	BTCC	Burn time cloud cover	[0-100%]	_____	_____	_____
39	BTHZ	Burn time haziness	[1-4]	_____	_____	_____

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

MOISTURE MODULE (continued, English Units)

LIST NUMBER _____

BURN TIME WIND

40	EXPOSURE	Exposure of fuels to wind	(1-5)	_____
		1 = exposed 2 = partially sheltered 3 = fully sheltered—open stand 4 = fully sheltered—dense stand 5 = direct entry of wind adjustment factor		
41	WAF	Wind adjustment factor Exposure 5 only	(0-1)	_____

MOISTURE INITIALIZATION OPTION

43	MOIS OPT	Moisture initialization option	(1-5)	_____
		1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing		

MOISTURE OPTION 1

44	FM-1	Burn day −1 fine fuel moisture	[1-100%]	_____	_____	_____

MOISTURE OPTION 3

51	RDAY	Number of days before burn that rain occurred	[1-7 days]	_____	_____	_____
52	RAIN	Rain amount, hundredths of an inch	[0-400]	_____	_____	_____
53	RDT	1400 temperature on rain day	[33-120 °F]	_____	_____	_____
54	SKY CODE	Sky condition from rain day to burn day	(1-3)		_____	
		1 = clear 2 = cloudy 3 = partly cloudy				

MOISTURE OPTION 4

No additional input.

MOISTURE MODULE (continued, English Units)

LIST NUMBER _____

MOISTURE OPTION 5

55	TD-1	Burn day −1 1400 temperature	[33-120 °F]	_____	_____	_____
56	RD-1	Burn day −1 1400 relative humidity	[1-100%]	_____	_____	_____
57	WD-1	Burn day −1 1400 20-ft windspeed	[0-99 mi/h]	_____	_____	_____
58	CD-1	Burn day −1 1400 cloud cover	[0-100%]	_____	_____	_____
59	WTHR	Weather condition prior to burn day −1 1 = hot and dry 2 = cool and wet 3 = between 1 and 2	[1-3]	_____	_____	_____

OUTPUT (Run)

1	MOIS	1-hour fuel moisture	pct	_____	_____	_____
2	TEMP	Fuel level temperature	°F	_____	_____	_____
3	%RH	Fuel level relative humidity	pct	_____	_____	_____
4	SHAD	Percent of area shaded	pct	_____	_____	_____
5	P(I)	Probability of ignition	pct	_____	_____	_____

MOISTURE MODULE (continued, English Units)

LIST NUMBER _____

HOURLY OUTPUT (Run)

TIME	FMOIST	FTEMP	FRH
	pct	°F	pct
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
Burn Time _____			

MAP MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	SCL OPT	Scale option 1 = Representative fraction 2 = Inches per mile	(1 or 2)			_____
2	RF/1000	[1]Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)			_____
3	IN/MI	[2]Inches per mile	(0.0625-8)			_____
4	UNITS OPT	Units option 1 = Spread distance 2 = Spot distance 3 = Rate of spread	(1-3)			_____
5	DIST	[3]Spread distance	[0-1000 ch]	_____	_____	_____
6	SPOT	[4]Spot distance	[0.1-10 mi]	_____	_____	_____
7	ROS	[5]Rate of spread	[0.1-500 ch/h]	_____	_____	_____
8	TIME	[5]Elapsed time	[0.1-8 h]	_____	_____	_____
5	FSD	[6]Forward spread distance	ch	_____	_____	_____
6	BSD	[6]Backing spread distance	ch	_____	_____	_____
7	MXW	[6]Maximum fire width	ch	_____	_____	_____
OUTPUT	(Run)					
1	MFSD	Forward spread distance on map (UNITS OPT = 1 or 3)	inches	_____	_____	_____
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	inches	_____	_____	_____
2	MBSD	Backing spread distance on map (SIZE linked only)	inches	_____	_____	_____
3	MMXW	Maximum fire width on map (SIZE linked only)	inches	_____	_____	_____

[1]Input only for scale option = 1.
[2]Input only for scale option = 2.
[3]Input only for units option = 1.
[4]Input only for units option = 2.
[5]Input only for units option = 3.
[6]Passed from SIZE for linked run only. No input is needed.

SLOPE MODULE (English Units)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

From Point _____ to Point _____

INPUT (Input, List)

1	SCL OPT	Scale option 1 = Representative fraction 2 = Inches per mile	(1 or 2)	_____
2	RF/1000	[1]Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)	_____
3	IN/MI	[2]Inches per mile	(0.0625-8)	_____
4	CON INT	Contour interval	(10-500 ft)	_____
5	MAP DIST	Map distance	(0.1-10 in)	_____
6	# INTVLS	Number of contour intervals	(1-100)	_____

OUTPUT (Run)

1	SLP %	Slope steepness	pct	_____
2	SLP DEG	Slope steepness	degrees	_____
3	EL DIFF	Elevation change	feet	_____
4	HORIZ DIST	Horizontal distance	feet	_____

[1]Input only for scale option = 1.
[2]Input only for scale option = 2.

WIND ADJUSTMENT MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	20'W	20-ft windspeed	[0-99 mi/h]	_____	_____	_____
2	EXPOSURE	Exposure to wind 1 = exposed 2 = partially sheltered 3 = fully sheltered, open stand 4 = fully sheltered, closed stand 5 = enter wind adjustment factor	(1-5)		_____	
3	WAF	[1]Wind adjustment factor	(0-1)		_____	
4	MODEL #	[2]Fuel model number	(1-99)		_____	
OUTPUT	(Run)					
1	MFWS	Midflame windspeed	mi/h	_____	_____	_____

[1]Input only for exposure = 5.
[2]Input only for exposure = 1.

RH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT (Input, List)

1	DRYB	Dry bulb temperature	[33-120 °F]	_____	_____	_____
2	WETB	Wet bulb temperature	[0-120 °F]	_____	_____	_____
3	EL	Elevation	[0-12,000 ft]	_____	_____	_____

OUTPUT (Run)

1	%RH	Relative humidity	pct	_____	_____	_____
2	DEWP	Dew point	°F	_____	_____	_____

ERROR CODES:

−888 = Wet bulb temperature greater than dry bulb temperature

−999 = Dew point too cold for valid calculations

TABLE NO. 1 TABLE ITEM: %RH ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

TABLE NO. 2 TABLE ITEM: DEWP ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

TWO MODULE (English Units)

(Keywords: Input, List, Run, Quit)

PASSED FROM DIRECT (List)

1	MODEL1	First model run by DIRECT			_____	
2	MODEL2	Second model run by DIRECT			_____	
3	ROS1	Spread rate for first model		_____	_____	_____
4	ROS2	Spread rate for second model		_____	_____	_____

INPUT (Input, List)

5	COV1	Percent area coverage first model	[20-80%]	_____	_____	_____

OUTPUT (Run)

1	ROS	Rate of spread	ch/h	_____	_____	_____

TABLE NO. 1 TABLE ITEM: Weighted ROS ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

OUTPUT TABLES

LIST NUMBER ______________

TABLE NO. _____ TABLE ITEM: ________________ ROW ITEM ________ COL. ITEM _____

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

TABLE NO. _____ TABLE ITEM: ________________ ROW ITEM ________ COL. ITEM _____

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

TABLE NO. _____ TABLE ITEM: ________________ ROW ITEM ________ COL. ITEM _____

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

FUEL MODEL MODULE (Metric)

(Keywords: Get, Input, List, Save, Quit, List Models, Delete Models)

INPUT LIST (Input, List)

1	MODEL #	Fuel model number	(14 - 99)	_____
2	NAME	Fuel model name	(22 char. max.)	_____
3	1HR LOAD	1-hour load	(0.02-70 M tons/ha)	_____
4	10HR LOAD	10-hour load	(0-70 M tons/ha)	_____
5	100HR LOAD	100-hour load	(0-70 M tons/ha)	_____
6	HERB LOAD	Live herb load	(0-70 M tons/ha)	_____
7	WOOD LOAD	Live woody load	(0-70 M tons/ha)	_____
8	1HR S/V	1-hour surface/volume ratio	(40-120 cm^2/cm^3)	_____
9	HERB S/V	[1]Herb surface/volume ratio	(40-120 cm^2/cm^3)	_____
10	WOOD S/V	[2]Woody surface/volume ratio	(40-120 cm^2/cm^3)	_____
11	DEPTH	Fuel bed depth	(1-300 cm)	_____
12	HEAT	Fuel heat content	(15,000-30,000 joules/g)	_____
13	MOIS EXT	Dead fuel extinction moisture	(10 - 50%)	_____
14	STATIC-DYNAM	Static or dynamic model 0 = static or herb load is zero 1 = dynamic	(0 or 1)	_____
15	WIND FACTOR	Exposed fuel wind adjustment factor	(0.01 - 1)	_____

[1]Input only if herb load is greater than zero.
[2]Input only if wood load is greater than zero.

USER FUEL MODEL FILE CONTENTS (List Models)

Model Number	Model Name (22 characters maximum)

DIRECT MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)		_____	
2	1H	1-H fuel moisture	[1-60%]	_____	_____	_____
3	10H	[1]10-H fuel moisture	[1-60%]	_____	_____	_____
4	100H	[1]100-H fuel moisture	[1-60%]	_____	_____	_____
5	HERB	[1]Live herb moisture	[30-300%]	_____	_____	_____
6	WOOD	[1]Live woody moisture	[30-300%]	_____	_____	_____
7	MFWS	Midflame windspeed	[0-160 km/h]	_____	_____	_____
8	SLP	Slope	[0-100% or 0-45 degrees]	_____	_____	_____
9	WDIR	[2]Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	_____	_____	_____
	PREDICT AT MAX		(Y/N)		_____	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)	[0-360 degrees]	_____	_____	_____
OUTPUT	(Run)					
0		No more tables				
1	ROS	Rate of spread	m/min	_____	_____	_____
2	H/A	Heat per unit area	kjoules/m^2	_____	_____	_____
3	FLI	Fireline intensity	kwatts/m	_____	_____	_____
4	FL	Flame length	m	_____	_____	_____
5	RI	Reaction intensity	kwatts/m^2	_____	_____	_____
6	EWS	Effective windspeed in direction SDIR	km/h	_____	_____	_____
7	MAXD	[3]Direction of maximum spread, deg. clockwise from uphill	degrees	_____	_____	_____

[1]Input only if corresponding fuel load is not zero.
[2]Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
[3]Output only if calculations are in direction of maximum spread.

SIZE MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, MAp, [1]COntain, Quit)

INPUT	(Input, List)					
1	ROS	[2]Rate of spread	[0.03-170 m/min]	_____	_____	_____
2	EWS	[2]Effective windspeed	[0-160 km/h]	_____	_____	_____
3	ET	Elapsed time	[0.1 - 8 h]	_____	_____	_____
OUTPUT	(Run)					
0		No more tables				
1	AREA	Area	ha	_____	_____	_____
2	PER	Perimeter	m	_____	_____	_____
3	L/W	Length-to-width ratio		_____	_____	_____
4	FSD	Forward spread distance	m	_____	_____	_____
5	BSD	Backing spread distance	m	_____	_____	_____
6	MXW	Maximum fire width	m	_____	_____	_____

[1]SIZE can link to CONTAIN only if linked to DIRECT.
[2]Input only when SIZE is used as an independent module.

CONTAIN MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = calculate total line building rate 2 = calculate burned area	(1 or 2)			
2	ATTACK OPT	Attack option 1 = head 2 = rear	(1 or 2)			
3	ROS	[1]Rate of spread	[0.03-170 m/min]			
4	AREA	[1]Initial fire area	[0.05-50 ha]			
5	L/W	[1]Length-to-width ratio	[1-5]			
6	BAT	[2]Burned area target	[0.1-1000 ha]			
7	TLBR	[3]Total line building rate	[0.1-250 m/min]			
OUTPUT	(Run)					
1	PER	Total length of line	m			
2	TIME	Containment time	hours			
3	FFS	[4]Final fire size	ha			
3	TLBR	[5]Total line building rate	m/min			
4	MAXA	[5]Maximum area calculable	ha			
5	MINA	[5]Minimum area calculable	ha			

Error Codes:

- −1 = Burned area target too large, cannot calculate slow enough line building rate
- −2 = Line building rate too slow to catch fire
- −3 = L/W ratio too large
- −4 = Burned area target too close to initial fire size
- −5 = Line building rate too fast

[1]Input only when CONTAIN is used as an independent module.
[2]Input only for run option = 1 (calculate total line building rate).
[3]Input only for run option = 2 (calculate burned area target).
[4]Output only for run option = 2.
[5]Output only for run option = 1.

APPENDIX B: (Con.)

SPOT MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, MAp, Quit)

INPUT	(Input, List)					
1	BRAND SRC	Firebrand source 1 = torching trees 2 = burning piles 3 = wind-driven surface fire	(1-3)		_____	
2	MCHT	Mean cover height	[0-100 m]	_____	_____	_____
3	10MW	10-meter windspeed	[0-160 km/h]	_____	_____	_____
4	RVEL	Ridge-to-valley elevation difference	[0-1,500 m]	_____	_____	_____
5	RVHD	Ridge-to-valley horiz. distance	[0-6 km]	_____	_____	_____
6	SRC LOC	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop	(0-3)		_____	
7	TREE SP	[1]Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir	(1-6)		_____	
8	DBH	[1]Torching tree DBH	[10-100 cm]	_____	_____	_____
9	TRHT	[1]Torching tree height	[1-100 m]	_____	_____	_____
10	#TR	[1]Number of torching trees	[1-30]	_____	_____	_____
11	FLHT	[2]Continuous flame height	[0.1-30 m]	_____	_____	_____
12	FL	[3]Flame length	[0.03-15 m]	_____	_____	_____
13	MODEL #	[3]Fuel model	(1-99)		_____	
14	HERB	[4]Herbaceous moisture	[30-300%]	_____	_____	_____
OUTPUT	(Run)					
1	SPOT	Maximum spotting distance	km	_____	_____	_____

[1]Input only for firebrand source = 1 (torching tree option).
[2]Input only for firebrand source = 2 (burning pile option).
[3]Input only for firebrand source = 3 (wind-driven surface fire option).
[4]Input only for dynamic fuel models with a herbaceous fuel load.

SCORCH MODULE (Metric)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[0-50 °C]	_____	_____	_____
2	FL	[1]Flame length	[0.03-5 m]	_____	_____	_____
3	MFWS	[1]Midflame windspeed	[0-16 km/h]	_____	_____	_____
OUTPUT	(Run)					
1	SCHT	Scorch height	m	_____	_____	_____

[1]Input only if SCORCH is used as an independent module.

TABLE NO. 1 TABLE ITEM: Scorch height ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

IGNITE MODULE (Metric)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[0-50 °C]	_____	_____	_____
2	1H	1-h fuel moisture	[1-60%]	_____	_____	_____
3	SHAD	Shade	[0-100%]	_____	_____	_____
OUTPUT	(Run)					
1	P(I)	Probability of ignition	pct	_____	_____	_____

TABLE NO. 1 TABLE ITEM: Prob. of Ignition ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

MOISTURE MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	RUN OPT	Run option 1 = Burn time calculations 2 = Hourly calculations	(1 or 2)			
TIME AND LOCATION						
2	BURN MONTH	Month of burn	(1-12)			
3	BURN DAY	Day of burn	(1-31)			
4	LATITUDE	Latitude of fire location	(−90 to 90 degrees)			
5	BURN TIME	Time of burn	(0-2,359 h)			
FUEL MODEL						
6	MODEL #	Fuel model number	(1-99)			
SLOPE, ELEVATION, ASPECT						
11	SLP	Slope steepness	[0-100% or 0-45 degrees]			
12	ELFL	Elevation of fire location	[0-4,000 m]			
	RH OBS AT FIRE		(Y/N)			
13	ELOB	Elevation of T&RH observations	(0-4,000 m)			
14	ASPECT	Aspect of fire location 0 = north 180 = south 90 = east 270 = west	(0-360 degrees)			
TIMBER OVERSTORY DESCRIPTION						
15	CCLO	Crown closure	[0-100%]			
16	FOLIAGE	Foliage presence 0 = absent 1 = present	(0 or 1)			
17	SHADE TOL	Shade tolerance 0 = intolerant 1 = tolerant	(0 or 1)			
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)			
19	AVHT	Average tree height	[3-100 m]			
20	H/H	Crown height/tree height ratio	[0.1-1]			
21	H/D	Crown height/crown diameter ratio	[0.2-5]			

MOISTURE MODULE (continued, Metric)

LIST NUMBER _____

EARLY AFTERNOON WEATHER

22	14T	Burn day 1400 temperature	[0-50 °C]	_____	_____	_____
23	14RH	Burn day 1400 relative humidity	[1-100%]	_____	_____	_____
24	14W	Burn day 1400 10-meter windspeed	[0-160 km/h]	_____	_____	_____
25	14CC	Burn day cloud cover	[0-100%]	_____	_____	_____
26	14HZ	Burn day 1400 haziness	[1-4]	_____	_____	_____

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

SUNSET WEATHER

27	SST	Sunset temperature	[0-50 °C]	_____	_____	_____
28	SSRH	Sunset relative humidity	[1-100%]	_____	_____	_____
29	SSW	Sunset 10-meter windspeed	[0-160 km/h]	_____	_____	_____
30	SSCC	Sunset cloud cover	[0-100%]	_____	_____	_____

SUNRISE WEATHER

31	SRT	Sunrise temperature	[0-50 °C]	_____	_____	_____
32	SRRH	Sunrise relative humidity	[1-100%]	_____	_____	_____
33	SRW	Sunrise 10-meter windspeed	[0-160 km/h]	_____	_____	_____
34	SRCC	Sunrise cloud cover	[0-100%]	_____	_____	_____

BURN TIME WEATHER

35	BTT	Burn time temperature	[0-50 °C]	_____	_____	_____
36	BTRH	Burn time relative humidity	[1-100%]	_____	_____	_____
37	BTW	Burn time 10-meter windspeed	[0-160 km/h]	_____	_____	_____
38	BTCC	Burn time cloud cover	[0-100%]	_____	_____	_____
39	BTHZ	Burn time haziness	[1-4]	_____	_____	_____

1 = very clear sky
2 = average clear forest atmosphere
3 = moderate blue haze
4 = dense haze—moderate smoke

MOISTURE MODULE (continued, Metric)

LIST NUMBER _____

BURN TIME WIND

40	EXPOSURE	Exposure of fuels to wind	(1-5)	_____
		1 = exposed 2 = partially sheltered 3 = fully sheltered—open stand 4 = fully sheltered—dense stand 5 = direct entry of wind adjustment factor		
41	WAF	Wind adjustment factor Exposure 5 only	(0-1)	_____

MOISTURE INITIALIZATION OPTION

43	MOIS OPT	Moisture initialization option	(1-5)	_____
		1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing		

MOISTURE OPTION 1

44	FM-1	Burn day-1 fine fuel moisture	[1-100%]	_____	_____	_____

MOISTURE OPTION 3

51	RDAY	Number of days before burn that rain occurred	[1-7 days]	_____	_____	_____
52	RAIN	Rain amount, millimeters	[0-100 mm]	_____	_____	_____
53	RDT	1400 temperature on rain day	[0-50 °C]	_____	_____	_____
54	SKY CODE	Sky condition from rain day to burn day	(1-3)			_____
		1 = clear 2 = cloudy 3 = partly cloudy				

MOISTURE OPTION 4

No additional input.

MOISTURE MODULE (continued, Metric)

LIST NUMBER _____

MOISTURE OPTION 5

55	TD-1	Burn day −1 1400 temperature	[0-50 °C]	_____	_____	_____
56	RD-1	Burn day −1 1400 relative humidity	[1-100%]	_____	_____	_____
57	WD-1	Burn day −1 1400 10-meter windspeed	[0-160 km/h]	_____	_____	_____
58	CD-1	Burn day −1 1400 cloud cover	[0-100%]	_____	_____	_____
59	WTHR	Weather condition prior to burn day −1 1 = hot and dry 2 = cool and wet 3 = between 1 and 2	[1-3]	_____	_____	_____

OUTPUT (Run)

1	MOIS	1-hour fuel moisture	pct	_____	_____	_____
2	TEMP	Fuel level temperature	°C	_____	_____	_____
3	%RH	Fuel level relative humidity	pct	_____	_____	_____
4	SHAD	Percent of area shaded	pct	_____	_____	_____
5	P(I)	Probability of ignition	pct	_____	_____	_____

MOISTURE MODULE (continued, Metric)

LIST NUMBER _____

HOURLY OUTPUT (Run)

TIME	FMOIST	FTEMP	FRH
	pct	°C	pct
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
Burn Time ____			

MAP MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

INPUT LIST (Input, List)

1	SCL OPT	[1]Scale option 1 = Representative fraction			1	
2	RF/1000	Representative fraction/1,000 e.g., RF of 1/100,000 = 100	(1-500)			
4	UNITS OPT	Units option 1 = Spread distance 2 = Spot distance 3 = Rate of spread	(1-3)			
5	DIST	[2]Spread distance	[0-20,000 m]			
6	SPOT	[3]Spot distance	[0.1-15 km]			
7	ROS	[4]Rate of spread	[0.03-170 m/min]			
8	TIME	[4]Elapsed time	[0.1-8 h]			
5	FSD	[5]Forward spread distance	m			
6	BSD	[5]Backing spread distance	m			
7	MXW	[5]Maximum fire width	m			

OUTPUT (Run)

1	MFSD	Forward spread distance on map (UNITS OPT = 1 or 3)	cm			
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	cm			
2	MBSD	Backing spread distance on map (SIZE linked only)	cm			
3	MMXW	Maximum fire width on map (SIZE linked only)	cm			

[1]Metric option sets the scale option = 1 (representative fraction).
[2]Input only for units option = 1.
[3]Input only for units option = 2.
[4]Input only for units option = 3.
[5]Passed from SIZE for linked run only. No input is needed.

SLOPE MODULE (Metric)

LIST NUMBER _____

(Keywords: Input, List, Run, Quit)

From Point ____ to Point ____

INPUT LIST (Input, List)

1	SCL OPT	[1]Scale option 1 = Representative fraction		1
2	RF/1000	[1]Representative fraction/1,000 e.g., RF of 1/100,000 = 100	(1-500)	_____
4	CON INT	Contour interval	(1-200 m)	_____
5	MAP DIST	Map distance	(0.1-25 cm)	_____
6	# INTVLS	Number of contour intervals	(1-100)	_____

OUTPUT (Run)

1	SLP %	Slope steepness	pct	_____
2	SLP DEG	Slope steepness	degrees	_____
3	EL DIFF	Elevation change	m	_____
4	HORIZ DIST	Horizontal distance	m	_____

[1]Metric option sets the scale option = 1 (representative fraction).

WIND ADJUSTMENT MODULE (Metric)

(Keywords: Input, List, Quit)

INPUT LIST (Input, List)

1	10MW	10-meter windspeed	[0-160 km/h]	_____	_____	_____
2	EXPOSURE	Exposure to wind 1 = exposed 2 = partially sheltered 3 = fully sheltered, open stand 4 = fully sheltered, closed stand 5 = enter wind adjustment factor	(1-5)		_____	
3	WAF	[1]Wind adjustment factor	(0-1)		_____	
4	MODEL #	[2]Fuel model number	(1-99)		_____	

OUTPUT (Run)

1	MFWS	Midflame windspeed	km/h	_____	_____	_____

[1]Input only for exposure = 5.
[2]Input only for exposure = 1.

RH MODULE (Metric)

(Keywords: Input, List, Run, Quit)

INPUT LIST (Input, List)

1	DRYB	Dry bulb temperature	[0-50 °C]	_____	_____	_____
2	WETB	Wet bulb temperature	[−18 to 50 °C]	_____	_____	_____
3	EL	Elevation	[0-4,000 m]	_____	_____	_____

OUTPUT (Run)

1	%RH	Relative humidity	pct	_____	_____	_____
2	DEWP	Dew point	°C	_____	_____	_____

ERROR CODES:

−888 = Wet bulb temperature greater than dry bulb temperature

−999 = Dew point too cold for valid calculations

TABLE NO. 1 TABLE ITEM: %RH ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

TABLE NO. 2 TABLE ITEM: DEWP ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

TWO MODULE (Metric)

(Keywords: Input, List, Run, Quit)

PASSED FROM DIRECT (List)

1	MODEL1	First model run by DIRECT			_____	
2	MODEL2	Second model run by DIRECT			_____	
3	ROS1	Spread rate for first model		_____	_____	_____
4	ROS2	Spread rate for second model		_____	_____	_____

INPUT (Input, List)

5	COV1	Percent area coverage first model	[20-80%]	_____	_____	_____

OUTPUT (Run)

1	ROS	Rate of spread	m/min	_____	_____	_____

TABLE NO. 1 TABLE ITEM: Weighted ROS ROW ITEM _____ COL. ITEM _____

Column Values: _____ _____ _____

Row No.	Row Value	Table Values		
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

OUTPUT TABLES

LIST NUMBER ____________

TABLE NO. ______ TABLE ITEM: ______________ ROW ITEM ________ COL. ITEM ______

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

TABLE NO. ______ TABLE ITEM: ______________ ROW ITEM ________ COL. ITEM ______

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

TABLE NO. ______ TABLE ITEM: ______________ ROW ITEM ________ COL. ITEM ______

Column Values: ________ ________ ________

Row No.	Row Value	Table Values		
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________

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Susott, Ronald A.; Burgan, Robert E. Fire behavior computations with the Hewlett-Packard HP-71B calculator. General Technical Report INT-202. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 80 p.

This report describes the operation of the fire behavior prediction program available as a Custom Read Only Memory (CROM) for the Hewlett-Packard model 71B handheld calculater. Worked examples are given for each of the 13 program modules, and the inputs and outputs are described. "Fire danger computations with the Hewlett-Packard HP-71B calculator," by Robert E. Burgan and Ronald A. Susott (1986) is a separate publication describing National Fire-Danger Rating (NFDR) system computations with the HP-71B.

KEYWORDS: fire behavior prediction, calculation aids, metric

INTERMOUNTAIN RESEARCH STATION

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